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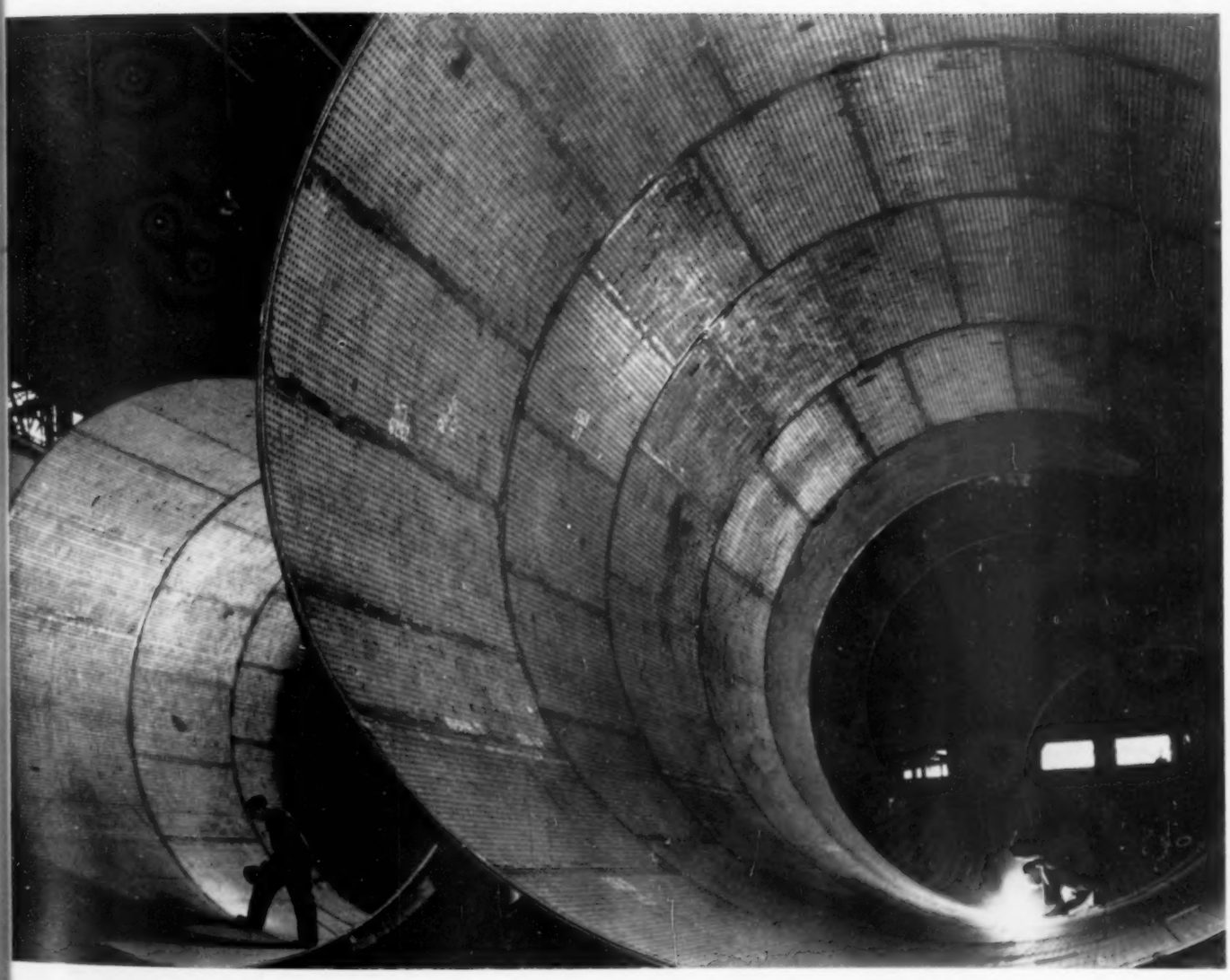

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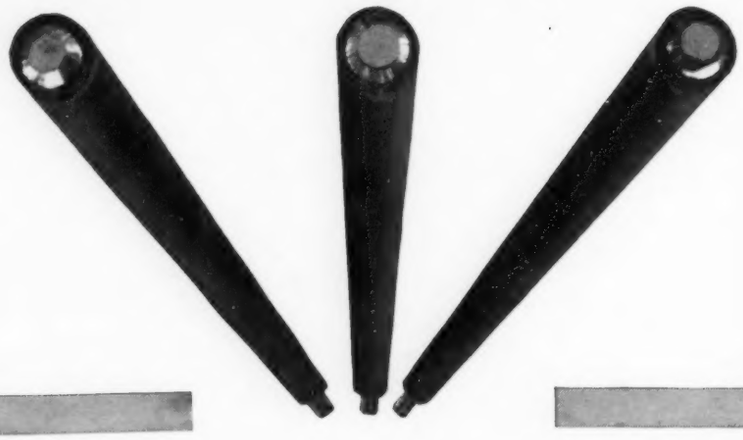

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Welding Journal
VOLUME 20, No. 6
JUNE, 1941

Welding for Impact Loading in Airplane Structures*

By Nairne F. Ward[1]

Summary

A PROCEDURE was sought which effectively utilizes welding for landing gear parts with a minimum of especially shaped materials of accepted quality. The evaluation of forces acting upon the welded strut in the essential requirements for stress determination under test, is shown. Butt and angle welds are described in accordance with special requirements of this design. The steel, selected for the welded structure, was S. A. E. X-4130 and was heat treated to develop optimum strength in tension and bending. The investigation demonstrates the need of controlling the weld deposit with proper joint design and welding procedure to obtain weld properties of maximum strength in a given structural unit. The paper discusses a method of drop testing a landing gear which is equally applicable to structures subjected to impact.

* Paper presented before Western Metal Congress, Los Angeles, May 19–23.
[1] Associate Professor of Mechanical Engineering, University of California, Berkeley. Visiting Lecturer of Metallurgy, Boeing School of Aeronautics, Oakland, California.

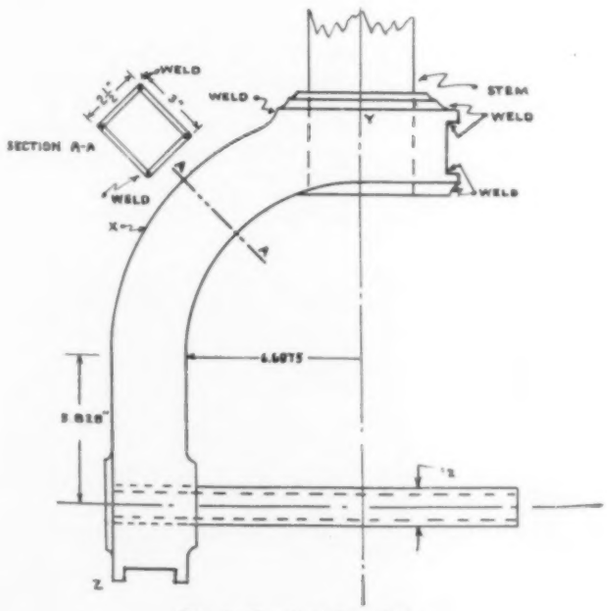


Fig. 1—Landing Gear Yoke

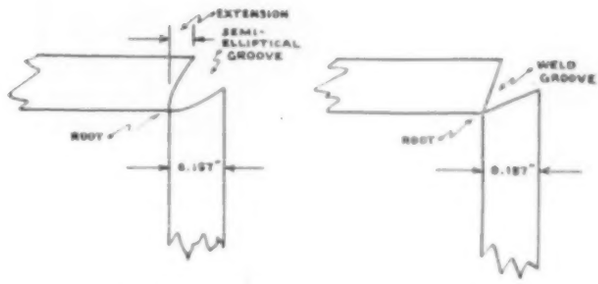


Fig. 2a Fig. 2b

The investigation, reported in this paper, was undertaken to insure a structure for a landing gear which left no question as to the magnitude of load permissible, yet with due consideration of economy in utilization of metal and processes without sacrifice of safety.

The Structure

The landing gear strut assembly, Fig. 1, was made up of the oleo cylinder, oleo strut stem, landing gear yoke and axle on which was the wheel, its rim and a 20-10-4-in. heavy duty tire. The landing gear assembly was fastened in the testing jig in the manner of mounting in the wing. The yoke was fabricated from flat stock of S. A. E. X-4130; first bent to form a 90° angle between sides, and second, bent in a jig to form the curvature in the shape of Fig. 1. In a jig, weld seams on opposite corners were deposited in semi-elliptical grooves, which were form milled, instead of the usual V-grooves formed at the juncture in Fig. 2 (*a*) rather than in Fig. 2 (*b*). From static tension tests it was found that welds deposited according to Fig. 2 (*a*) in flat specimens were at least 10% better in strength than according to Fig. 2 (*b*), without heat treatment, and as high as 40% better for heat-treated welds, when made according to the same procedure control. Each weld was deposited with a neutral oxyacetylene gas flame and high test filler rod, using No. 23 tip size for closure of the root seam and two additional passes with No. 25 tip size, at all times with minimum sparking in the welding. Explanation for the improved quality of welds by this procedure will be verified in a later section of the paper.

Welding in the curved seams, necessitated by this de-

Table 1—Static Tension Test Results

Condition	Yield Stress,* Lb. per Sq. In.	Ultimate Stress	Elongation, % in 2 In.	Rockwell Hardness Parent Metal
Original as received	93,000	121,000	17½	C-11
Original as heat treated. Quench in oil from 1700° F., draw 770° F.	150,000	174,500	10	C-38.5
45° notch weld, untreated	82,000	95,500	15	C-11
Semi-elliptical notch weld, untreated	90,000	104,000	11	C-11
45° notch weld, heat treated as above	75,000	87,500	10	C-31
Semi-elliptical notch weld, heat treated as above	105,000	120,000	9½	C-32

* Yield point stress was determined at 0.2% of total elongation in accordance with Federal Specification QQ-M-151a.

Fig. *A*—In Weld of Unheat-Treated S.A.E. X-4130 Steel. Mag. 390X 5% Nital Etch

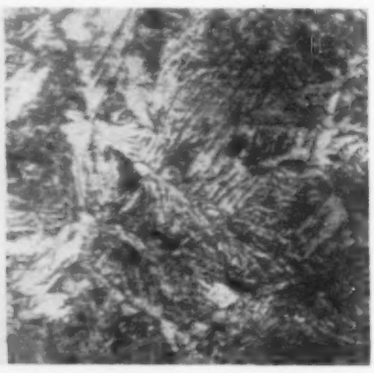


Fig. *B*—In Transition Zone of S.A.E. X-4130 Steel. Not Heat Treated. Mag. 390X. Nital Etch

sign, was accomplished in a semi-covered jig of corresponding shape, exposing the seams at their weldable edges. Welds were deposited in three successive passes as previously mentioned for four running welds, starting at *X*, Fig. 1, and upon completion to point *Y*, Fig. 1. The remainder of the four seams were welded in the same manner on the seam opposite *X* and to a point opposite to point *Y* in three passes. This procedure compensated for possible distortion. The total seam was completed from *Z* to *X*, and the final weld placed opposite point *X* to position *Z*. Each weld was subjected to reheating at a dull red heat upon its completion and allowed to cool slowly in air, followed by heat treatment of complete section to develop optimum strength.

Test of Coupon Welds

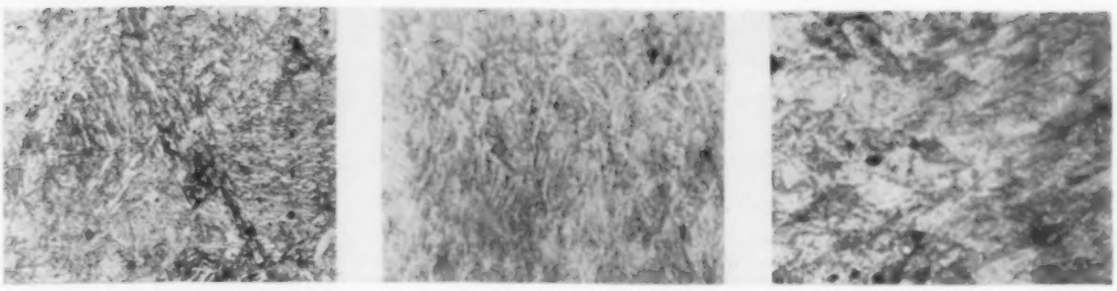
Specimen welds were used to establish the best technique for depositing the weld for each type of groove. A series of weld coupons were prepared from flat stock according to the aforementioned procedure. One series was made with 45° V-groove simulating the joint naturally existing with slight scarfing of the plate, Fig. 2 (*b*). Another series was welded with the same procedure control but with weld grooves, semi-elliptical in shape, with minor axis, Fig. 2 (*a*), 10% less than one half the major axis. The increase of 10% provides for the extension of the outermost fibers at the surface of the weld, equivalent to the elongation experienced in heat-treated weld specimens under tensile stress. The resulting distribution of stress in the weld, either due to shrinkage upon cooling or under stress or a combination of effects, approaches the uniform condition of the weld deposit of circular cross section, demonstrable by an equivalent rubber model of the joint.

Physical properties of the types of welds are given in the Table 1 for an average of three specimens, except the original S. A. E. X-4130. The thickness of each specimen was the same and equal to 0.1563 in., while retaining the bead reinforcement. The heat-treated welds varied from the best to the lowest within each group within 5% of the ultimate strength. Similar welds made with the direct current, open arc and coated electrodes developed a maximum strength of 85,000 lb. per sq. in. and were not given further consideration because this represented the optimum of several techniques, for multiple bead arc welds, after heat treatment.

Possible causes of variations encountered in static

1. In Weld 2. In Transition Zone 3. Parent Metal

Fig. *C*—Photomicrographs of Heat Treated S.A.E. X-4130 Steel with 45° Notch Welds. Mag. 390X. Nital Etch



1. In Weld 2. In Transition Zone 3. Parent Metal

Fig. *D*—Photomicrographs of Heat Treated S.A.E. X-4130 Steel with Semi-Elliptical Notch Weld. Mag. 390X. 5% Nital Etch

tension tests were investigated by photomicrographic study of 45° notch welds and semi-elliptical notch welds. The original microstructures for the specimens as welded, without heat treatment, appear in Fig. *A* and the weld metal as deposited in Fig. *B*.

Photomicrographs of the two types of weld groove appear in Fig. *C* for 45° notch welds and Fig. *D* for semi-ellipitical welds. Variation of grain size, fusion defects, contamination were not revealed as differing materially in the two types of welds or the accompanying groove shape. The absence of adverse evidence from the standpoint of metallic composition gives sufficient basis for attributing the more favorable properties of the semi-elliptical groove weld to adjustment of stress due to shrinkage or to external loading or their combination within the confines of the weld deposit and affected areas.

Drop Test of Assembled Gear

A series of drop tests of the completed strut, including the welded yoke, Fig. 1, were conducted at or near induced stresses approaching design stress.

A test jig was used, consisting of two 10-in. channels, lattice-braced and hinged to simulate level and three-point landing positions of the equivalent airplane. On he end of the jig, opposite to the hinge, the landing gear assembly was mounted as in service and is shown in Fig. 3.

Forward in the landing gear mounting of the test rig, provision was made for loading by lead weights. The weights were so distributed as to impose on the single wheel landing gear assembly, the load of 1375 lb. which is the load apportioned for a single wheel in three-point landing position. The critical loading of the strut assembly was found to be in the three-point landing position, by preliminary tests with an accelerometer for the drop of 23.4 in., which is equivalent to 24 in. displacement in line of strut stem, when corrected for the angle of advance of the gear, Fig. 3. The accelerometer was mounted directly above the strut and had $^1/_{25}$ second minimum damping which was within the legal requirement of $^1/_{20}$ second.

With the view of obtaining more specific values of load intensities, a recording unit was built and installed by the Boeing School of Aeronautics for these tests. The recording unit consists of a drum, Fig. *E*, to which is attached, paper for graphical record, and which is rotated synchronously, two revolutions per second. The record is made by pencils, traversing parallel to the axis of the drum, and actuated by two independently attached steel picture wire cables of pre-stressed wire, one of which was fastened to the top of the strut and the other to the yoke near the axle. The curves traced by this recording mechanism during the drop tests, before the oleo strut is actuated, are separated by the vertical distance between the pins of attachment. See Fig. 4 for a sample record. Added to this record is the displacement-time

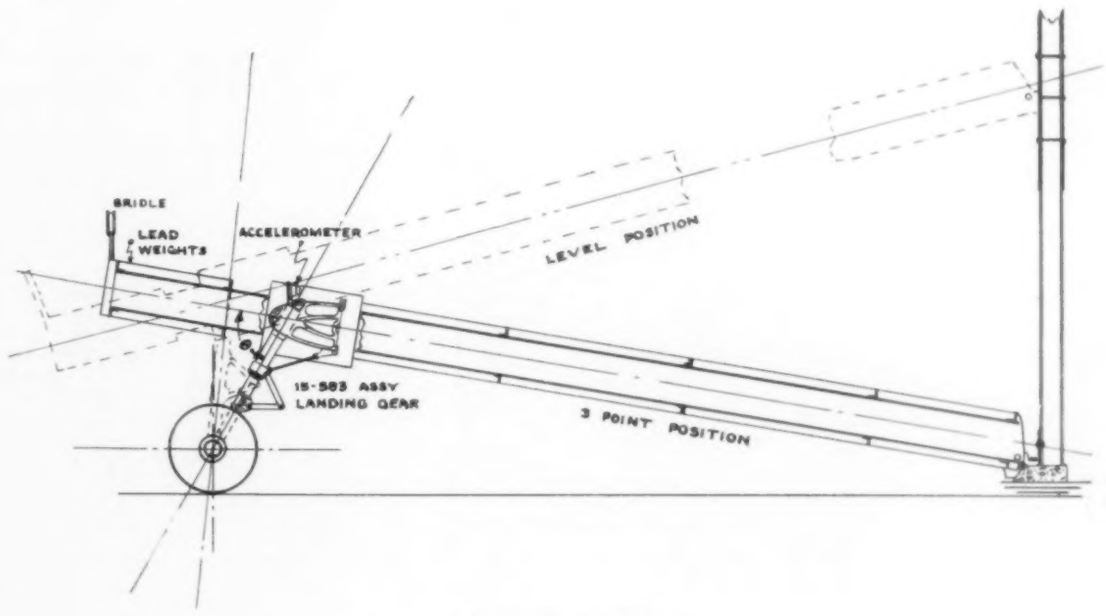
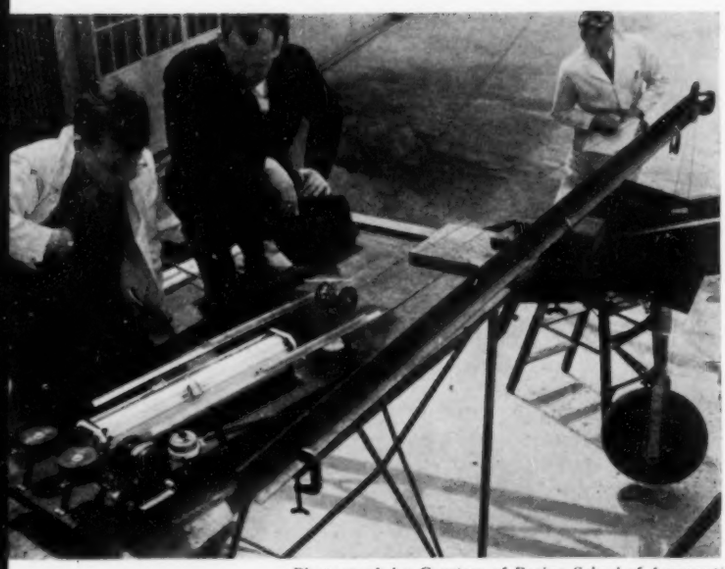


Fig. 3—Drop-Test Jig



Photograph by *Courtesy of Boeing School of Aeronautic*

Fig. E—Test Rig Showing High Speed Recorder and Landing Gear Ready for Drop Test

curve of the strut yoke which has been corrected for the angle (θ), Fig. 3, for approximately half of the time of descent of the load or until the strut velocity approached zero. For the test, shown in Fig. 4, the accelerometer registered 6.5*xg* which, if the velocity curve is evaluated, is approximated between points *a* and *b* in Fig. 4. For maximum velocity the strut displacement curve may be seen to have several reverse loops in it due to combined effects of tire bounce and inertia in the recording mechanism. However, if the combined results on this record are averaged, the trend in the displacement-time curve, and velocity derived therefrom, approximates the simple harmonic motion of the jig in Fig. 5.

Not shown in Fig. 4 are the harmonics of higher order accompanying the combined damping effect of the several jig parts, since their resulting magnitude is less than the maximum intensity of the first drop. Successive minor accelerations attending tire bounce and consequent rebound of the apparatus impose loads of decreasing intensity and less than critical value. The tire and spring in the oleo unit finally reach their separate static positions, which are shown by the horizontal lines in Fig. 4.

The importance of this test is, mainly, to determine the maximum load applied to the strut yoke. The determination is made from a combination of graphical differentiations of the strut displacement-time curve, Fig. 5, which yields the velocity of the strut, Fig. 6. Further graphical differentiation of the positive velocity curve, Fig. 6, produces the acceleration of the strut during

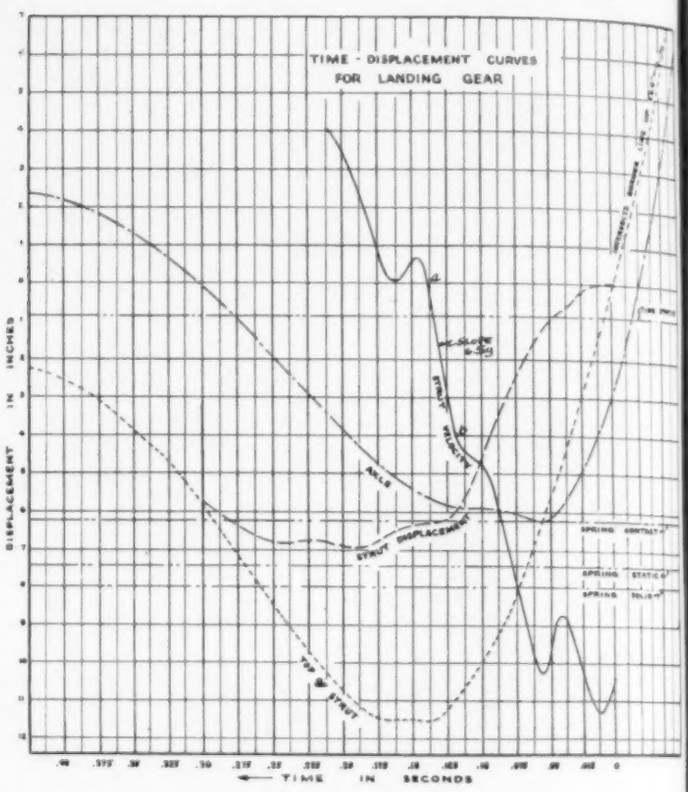
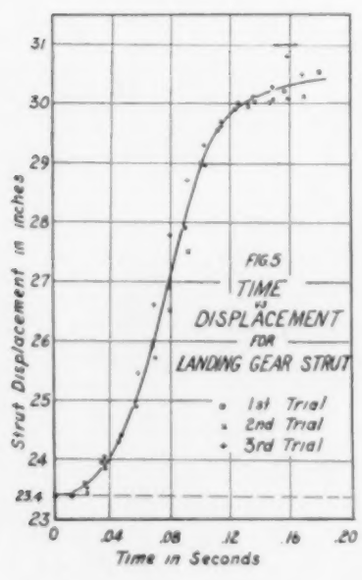
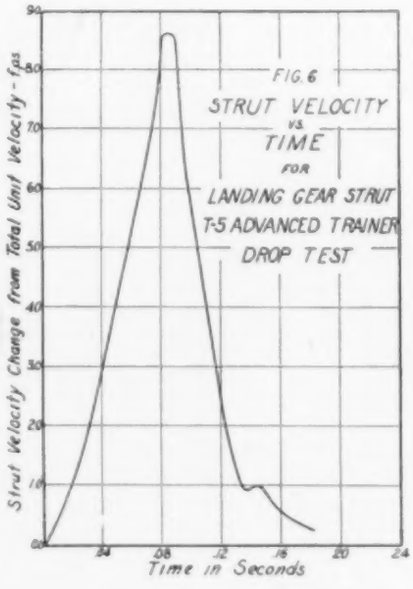


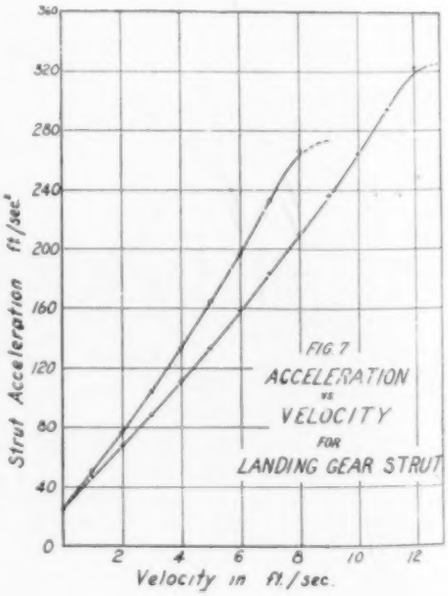
Fig. 4

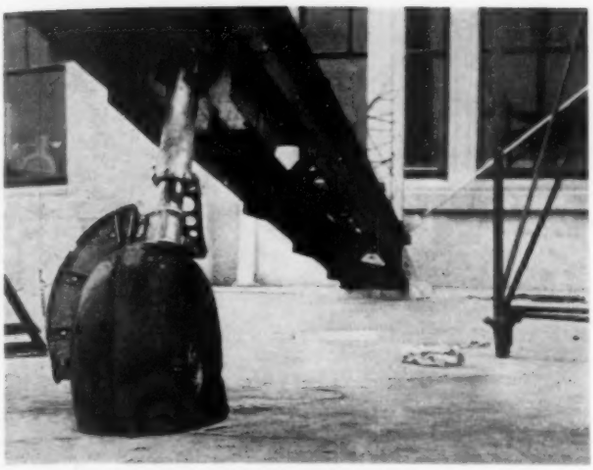
descent in the test. When the corresponding velocities and accelerations are correlated by each drop test, the results, shown in Fig. 7 are obtained.

Successive drop tests were taken varying from 4.5*xg*









Photograph by *Courtesy of Boeing School of Aeronautics*

Fig. F—Drop Test in Action. Note Symmetry of Tire Deformation

accelerations to and including 7.4xg acceleration according to the accelerometer. Inadvertently, one drop developed an acceleration 9.2xg without producing measurable permanent set in the welded yoke, or axle.

For a series of three drop tests with 6.4xg, 6.5xg and 6.6xg, nominal accelerations, the velocity curve was determined from the average displacement-time curve, Fig. 5, and the acceleration of the strut from velocity curve, Fig. 6. The corresponding accelerations and velocities are combined in Fig. 7, from which the equivalent force is computed from the relation

$$F = \frac{W}{g} \times \text{acceleration}$$

where W is weight in pounds and g is acceleration due to gravity. The weight of the strut yoke, axle, tire and rim, amounting to 59.95 lb. has been deducted from the load of 1375 lb. in all of these calculations.

The curve for 6.5xg average of nominal acceleration, appearing in Fig. 7, is very closely approximated by the equation

$$R = a_0 + a_1 v + a_2 v^2$$

where R = total resistance to imposed load in lb.
a_0 = constant for static friction and inertia
a_1 = constant for elastic fluids—air, tire
a_2 = constant for viscous flow—oil in oleo principally
v = velocity of strut in feet per second.

a_1 and a_2 are determined from simultaneous equations for successive points on curves similar to Fig. 7. This equation for 6.5xg acceleration reduces to

$$R = 1070 + 953v + 33.7v^2$$

The maximum velocity attained in this particular test was 8.5 ft./sec. The force, absorbed by virtue of the fact, the load was transmitted through the strut yoke and axle to the tire, Fig. F. This amounts to, within the accuracy of the graphical method, 8100 lb., which compares with the design load component of 6522 along the line of action of the strut and the point of contact of the tire. Inspection revealed no evidence of overstressing in either original or parent metal.

A similar procedure was used for 9.2xg acceleration, during which the maximum velocity was 12 ft. per second. From equation of curve (2), Fig. 7

$$R = 1070 + 776.4v + 19.2v^2$$

the maximum load, within the accuracy of the graphical method, was 9315 lb. in comparison with the design load of 6522 lb. This test showed no evidence of weakness in either original or parent metal. The magnitude of accelerations were considered ample for conservative operation of this airplane, and producing loads in the landing gear within the limits of safe operation.

Acknowledgment

Recognition of responsibility for the design of this landing gear is given Mr. J. W. Thorp of the Boeing School of Aeronautics. The weld specimens, and the welding of the landing gear was the work of Mr. H. R. Brentlinger, Head of the Maintenance Department of the Boeing School of Aeronautics. The tests were made possible by the combined facilities of the Boeing School of Aeronautics, Oakland, California, and the University of California at Berkeley.

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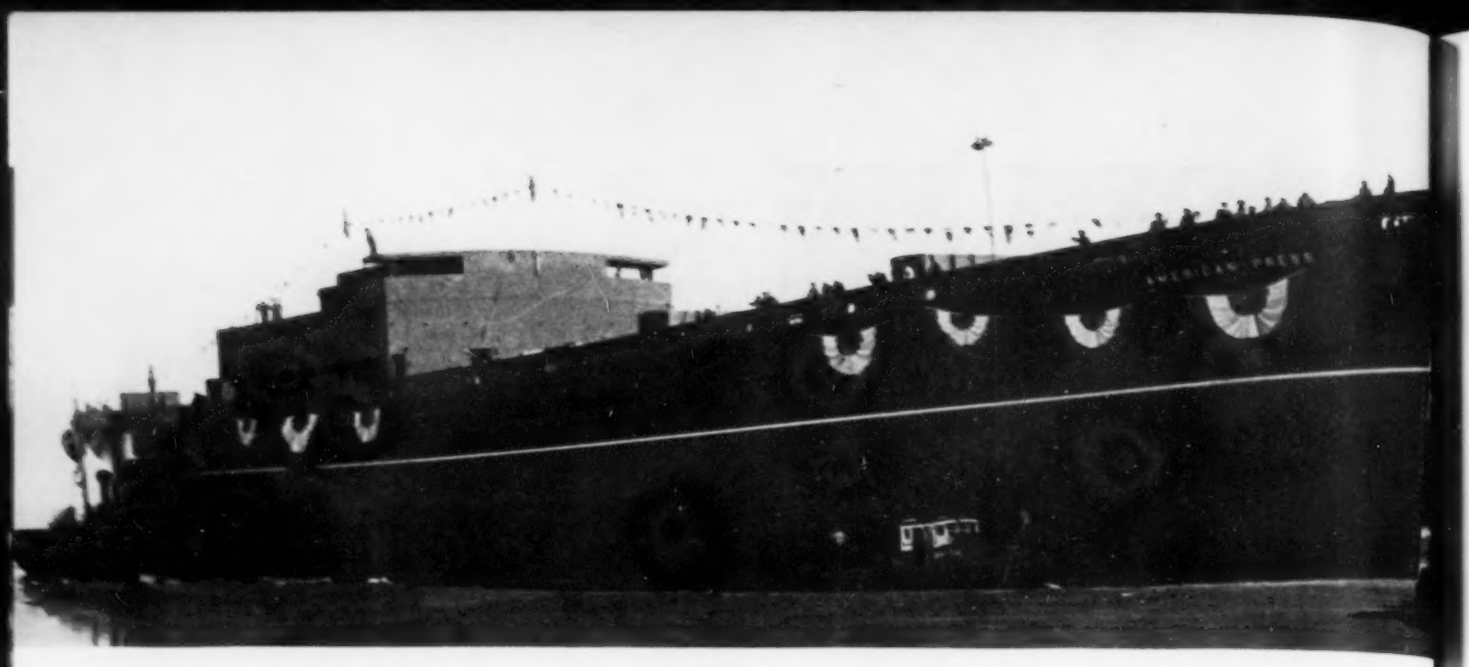


Fig. 1

All Welded Ships*

By L. W. Delhi† and M. N. Maltseff‡

WHEN, late in 1939, the Western Pipe and Steel Company of California was awarded a contract to construct five C-1B Diesel-powered cargo ships for the United States Maritime Commission, it was necessary, due to the fact that no ships of this size had been constructed or detailed for welded construction, that we secure the services of experienced Naval Architects who were in sympathy with, and experienced in, welded hull design, and immediately come to a decision as to the percentage of the work that was to be welded, and the design and details of that welded work.

After consultation with members of the United States Maritime Commission it was decided to employ Mr. George G. Sharp's organization as they had had recent experience in detailing an "All Welded" hull, and were in agreement with the United States Maritime Commission, who unqualifiedly approved welding for every detail of the construction that the Western Pipe and Steel Company chose to make welded.

Therefore, because of the confidence expressed in welding by the United States Maritime Commission, the American Bureau of Shipping and Mr. George G. Sharp's organization, we chose, after a very brief consultation, to go "All Welded," using no rivets any place in the ship, and departing as much as conditions permitted from the practice of using a riveted design and merely substituting welding for riveting. This departure involved the use of angle sections or bent plates instead of channels, and eliminated buttstraps and lap joints. Time was too short to develop the use of alloy steel or higher tensile-strength steel in the design of the hull, therefore complete advantage has not been taken of the savings possible in an "All Welded" hull.

The decision to go "All Welded" being made, it was necessary to immediately consider the factors or problems that would confront us in our efforts to take full advantage of the possible benefits in going "All Welded."

Preliminary examination developed seven factors we believed advantageous to the welding of the hulls, not only from the point of view of the shipbuilder, but also of the owners; and also six factors concerning the design detail of certain particular parts of the hull that we believed should be subjected to considerable analysis and study to fully develop the benefits of welding, and this paper will have to do only with those factors that we feel are of special interest to the "Welding Fraternity," and is not presumed to be a treatise on ship building.

The first seven factors were: *1. Saving in Weight.* Practical welders and theorists, alike, agree that rolled symmetrical sections are ideal for designing welded construction, and in the design room T-Bars cut from I-Beams or rolled in sections are usually embodied, however, when the material lists are sent to the mills, it is invariably found that the sections required are not available—at least, not in time to be of any use to the shipbuilder—so that the latter has to resort to building up the required section, or to use an inverted angle (or if a larger section is required, a channel with one flange burned off). This situation has been going on ever since welded construction became the vogue with shipbuilders with advanced outlook, and although the large steel producers have been approached with a view to cooperating with the shipbuilding industry in order to put in rolls for a range of symmetrical rolled sections, no action has yet been taken by them. It may be that present world conditions, creating a condition of maximum capacity production in the steel mills, is the real cause for this apparent lack of cooperation; and we must, therefore, look to the future in the hope that the steel manufacturers will be able to produce symmetrical sections which will result in better welded construction design. As an example of the above: Using inverted angles instead of bulb angles, or channels, permits lighter sections for frames, bulkhead stiffeners and similar structural members. For instance: A 4 inch x 3 inch x 9.8 lb. inverted angle is equivalent to a 6 inch x 3 inch x 11.7 lb. bulb angle; and a 10 inch x 4 inch x 17.9 lb. inverted

* Presented at Western Metal Congress held in Los Angeles, Calif., May 19 to 23, 1941.

† Vice-President, Western Pipe and Steel Co., San Francisco.
‡ Welding Engineer, Western Pipe and Steel Co., San Francisco.

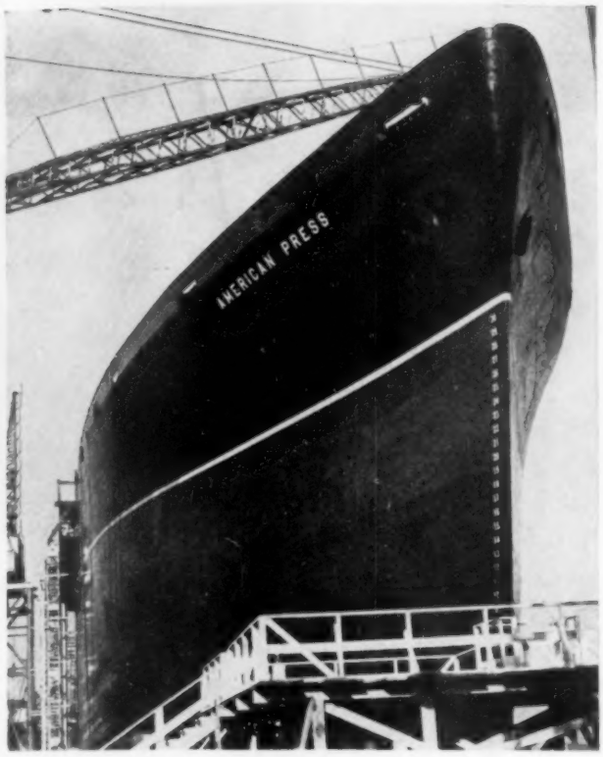


Fig. 2

flanged plate is equivalent to a 9 inch x 3.45 x 23.9 lb. channel.

2. *Less Skin Friction.*—The elimination of outside laps, buttstraps and rivet heads facilitates the painting and cleaning of the hull and tends to reduce frictional resistance, and it is estimated that, where the total propulsional resistance is 52,800 lb., the skin friction amounts to 19,536 lb. and the resistance of butts, plate edges and rivet heads would be approximately 3% of the latter, or 586 lb. Translated into speed, the above figures indicate the speed of the "All Welded" ship under discussion would be increased approximately 0.06 of a knot over that of an "All Riveted" ship.

3. *Less Detailing and Mold Loft Work.*—The elimination of rivet holes, and the use of panel assemblies, reduces the labor involved in developing detailed hull drawings by a considerable amount, and shortens the drafting time by some few thousand man-hours. It also reduces direct labor in marking off plates in the shop by more than one-third, as many panels of decks and bulkheads do not require patterns for each plate; in fact, many panels are dimensioned on the welding jigs by pegs or measurements instead of by pattern. Consequently, the mold loft labor and pattern materials are likewise greatly reduced.

4. *Less Shop Fabrication.*—It is obvious that the elimination of rivet holes, buttstraps, joggled plate edges and liners greatly reduces the machine-hours and man-hours required for punching and other operations necessitated by riveted work. In fact, only the bilge strakes which go through the rolls, and approximately thirty additional shell plates that require rolling and forming under the press, go to any fabricating machine; over 95% of the plates go directly from the plate rack to the planer or the burning table after being marked off.

As to the cost of hanging plates, bolting, reaming, riveting and caulking on a riveted hull, compared to the cost of hanging plates, tacking and welding on an "All Welded" hull, we are not prepared at this time to present figures or even offer an opinion.

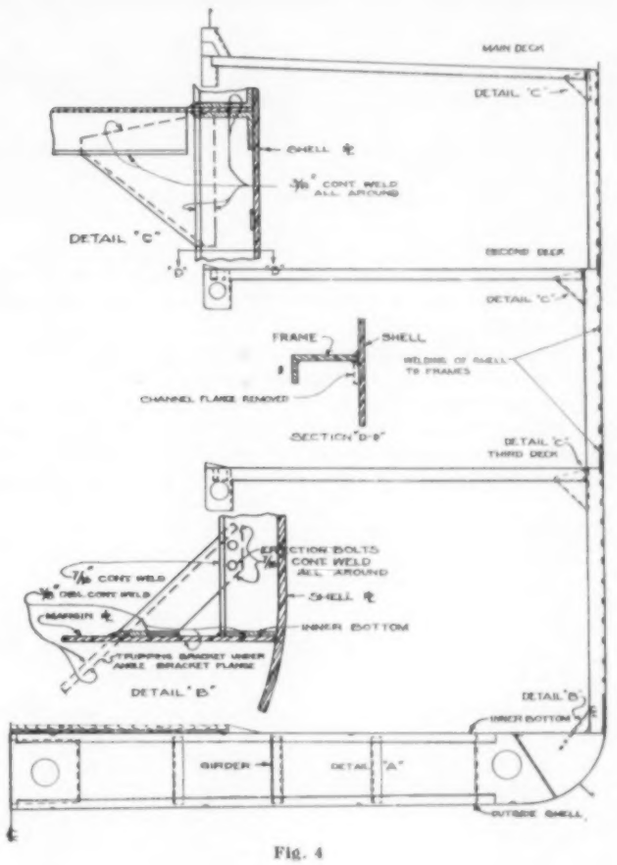


Fig. 4

5. *Fewer Crane Lifts.*—The work of preassembling the double bottom sections, decks and bulkheads, totaling about 147 subunits, can be done elsewhere than on the shipways, which greatly reduces the amount of crane service required at the ship side, the man-hours aboard ship and, consequently, proportionately decreases the confusion and shortens the erection schedule. A comfortable schedule on an "All Welded" C-1B type of hull from keel laying to launching is 80 to 85 working days, doing much welding on the second shift and some catch-up welding on the third shift.

6. *Less Plant and Erection Facilities.*—An "All Welded" hull can be almost entirely fabricated in the shop with an angle shear, plate shear, press, rolls, plate bender, and burning and welding equipment, eliminating

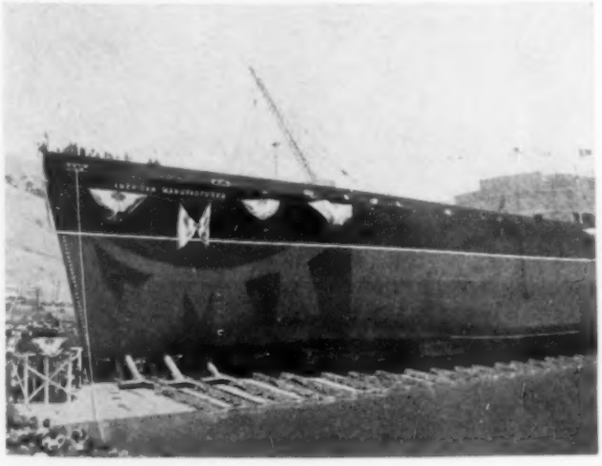


Fig. 3

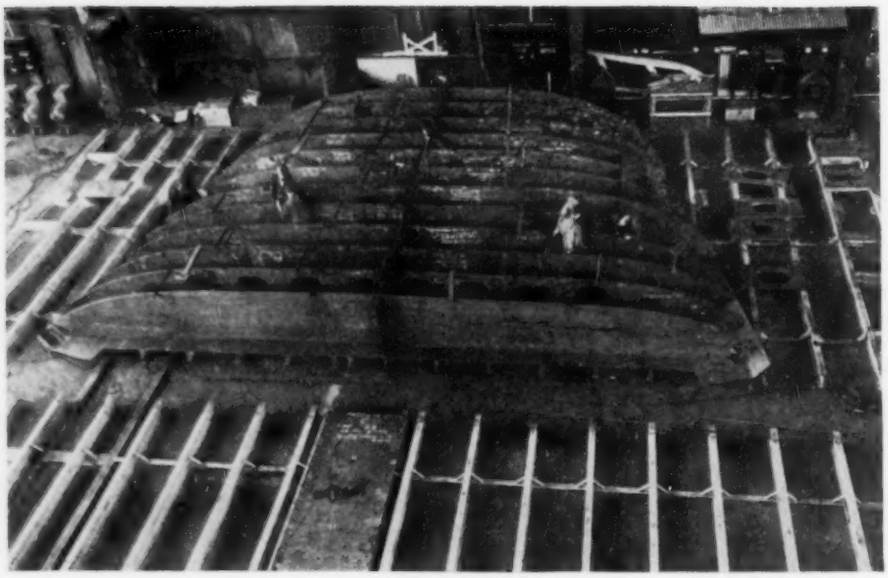


Fig. 5

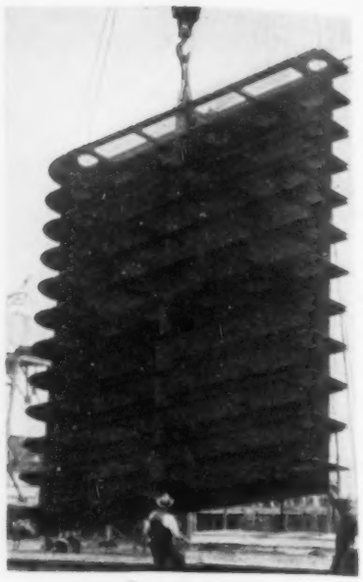


Fig. 6

all punching, drilling, reaming and countersinking equipment and considerable forge equipment and compressor capacity.

Erection equipment, exclusive of cranes, consists of approximately 100 welding units per hull together with the necessary burning equipment and fitting-up devices to serve the fitting and welding crews.

7. *More Strength and Cleaner Lines.*—It is acknowledged that any good hand or automatic weld will normally develop a 100% joint, whereas the efficiency of a riveted butt joint in ship construction is usually 80 to 90%, and the efficiency of the riveted lap joint on the horizontal seam is frequently under 70%.

In designing the hull for the C-1B type of cargo vessel, the United States Maritime Commission effected a considerable refinement of the molded lines, reducing the block coefficient from an approximate 0.80 for comparable ships built in our yard during the first World War, to an approximate 0.67 in the new ships. The finer lines of the ship (see Fig. 1) plus the butt welding of all seams, adds greatly to the beauty and shape of the hull and likewise permits a substantial increase of speed over the old design (see Figs. 2 and 3).

Such fineness of lines, however, added somewhat to the cost of erection at first as the problem of hanging, tacking and fairing up of the formed plates for welding required the development of special clips and devices for pulling in the plates, and particularly the training of shipfitters who had never handled any but riveted plates before. It took a goodly amount of effort and patience to train the leading men and shipfitters to properly handle these plates having no holes for bolting up purposes.

The second group of six factors of particular interest to the Welding Fraternity were:

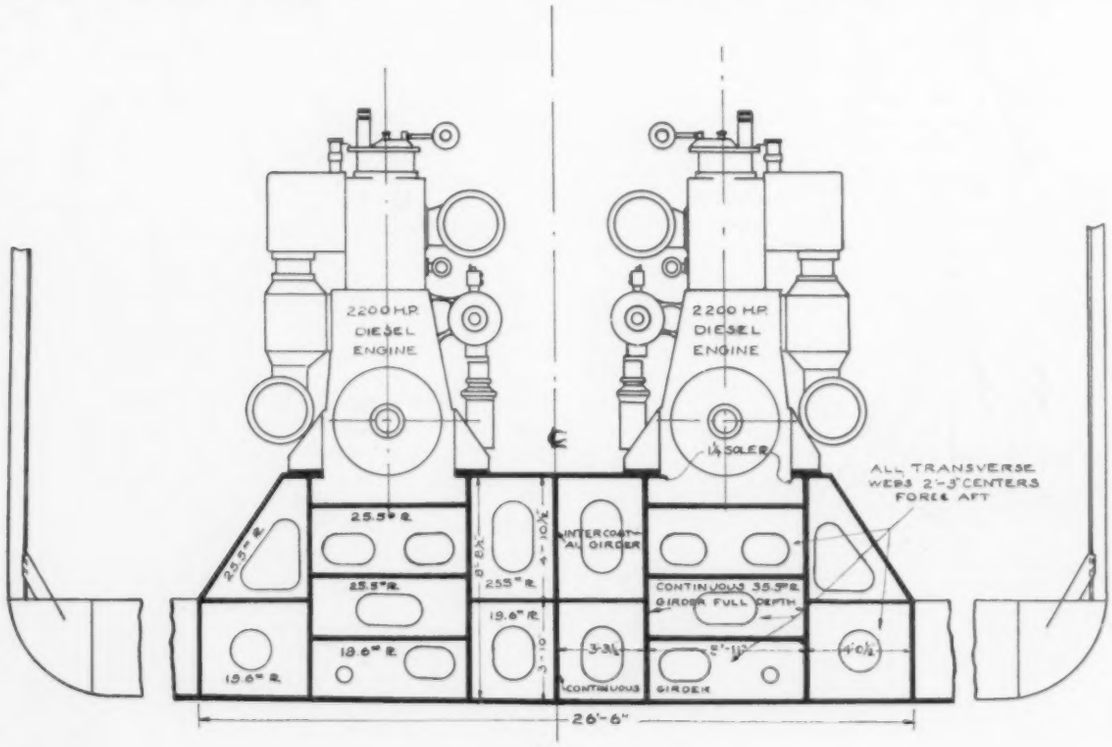


Fig. 7

1. Design of double bottom, sides and deck connections.
2. Adaption of welding to Diesel engine foundations.
3. Welding sequence to prevent shrinkage and locked-up stresses.
4. Expansion joints and their function.
5. Method of Welding Stern Castings and adjacent frames and floors to prevent lifting.
6. Method of welding light plates in superstructure.

1. Design of Double Bottom, Sides and Deck Connections.—Figure 4 shows the details of a typical midship section developed with the idea of having the simplest possible design to facilitate the erection, fitting and welding of the hull. Detail *A* indicates the transverse double bottom framing adopted in general throughout the ship in order to eliminate as much weight as possible; only every fifth frame is solid. In many instances in the past solid floors with lightening holes cut therein have been used, and these have been somewhat awkward for the fitting and welding of the longitudinal girders, floors and other welded connections. The adoption of open framing not only saved considerable weight, but allowed ingress and egress for the welders to more satisfactorily prosecute their work.

The double bottom consists of 16 sections, 60 feet wide at the midship section, tapering rather finely forward and aft, and somewhat more than 25 feet long. Each double bottom section was fitted together and welded as much as possible in the shop, in sections half the width of the ship, and having a maximum weight of 14 tons. In each case, the structural frames were assembled in jigs in the structural shop and hand welded, then transported to the assembly floor in the main shop where the complete double bottom was assembled on a series of fitting-up jigs (see Fig. 5) consisting of rather heavy I-beams imbedded in concrete in the floor of the shop, and so spaced and leveled as to permit of the fitting up and automatic welding of all the panels of plates from two sides, using a tractor type automatic welding machine. The inner bottom frames were then properly spaced on the panels, and the double bottom sections were fitted and welded before transporting to the ship ways (see Fig. 6) for the final erection.

Detail *B* (Fig. 4) shows an interesting development in welding side frames to the margin plate and shell plates. In this instance, as well as in the welding of the double bottom sections, full recognition was given to the efficiency of a welded joint. Note that the frame consists of an angle section, the flange of the channel section required for riveting having been eliminated, and the base of the frame is welded directly to the margin plate without benefit of clips or other reinforcing except the knee brace shown. For erecting purposes, the frames were spaced on an assembly table alongside the ship and two or four plates were tack welded together and to the

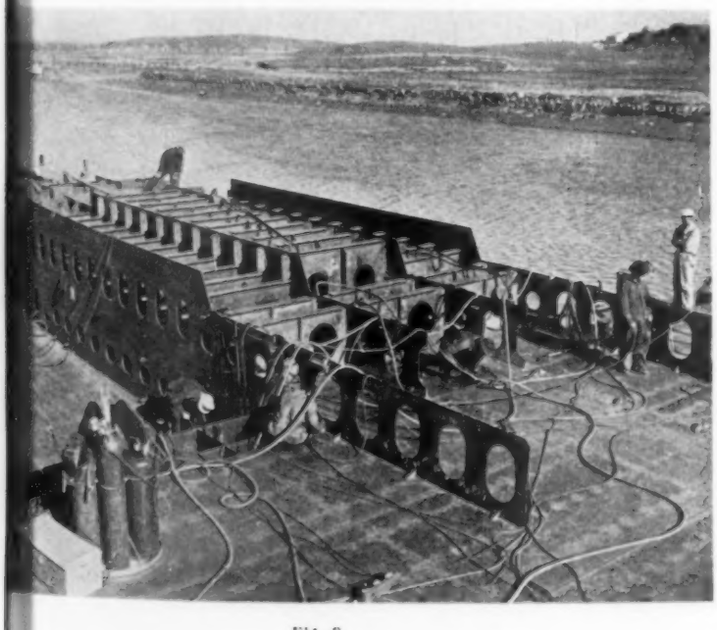
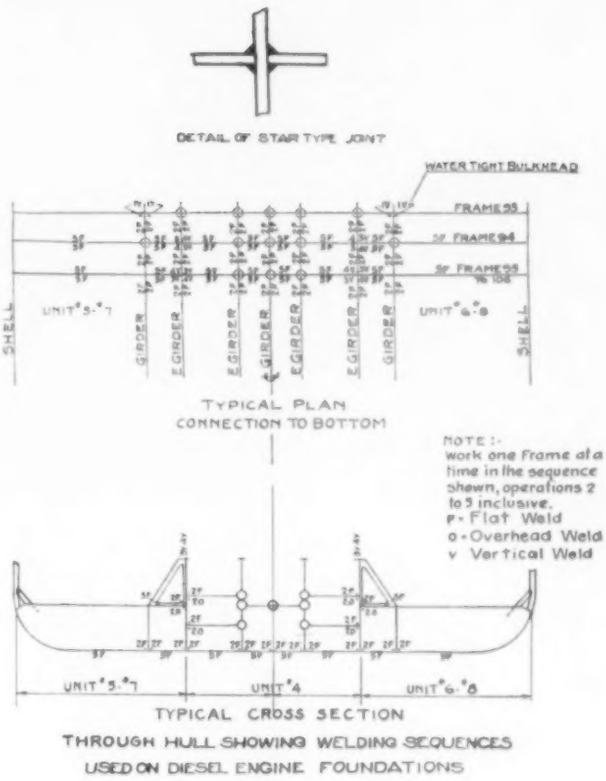


Fig. 8

Fig. 9



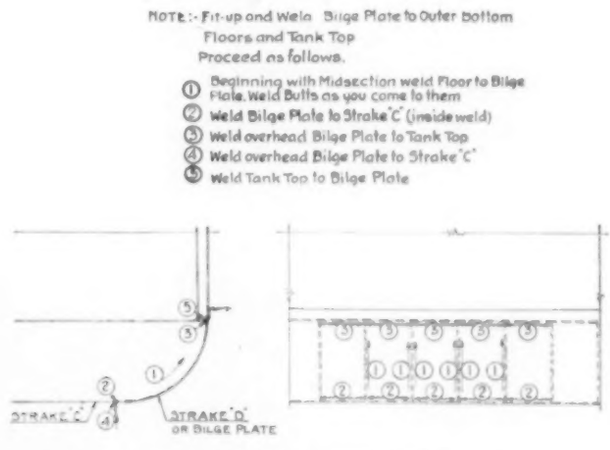
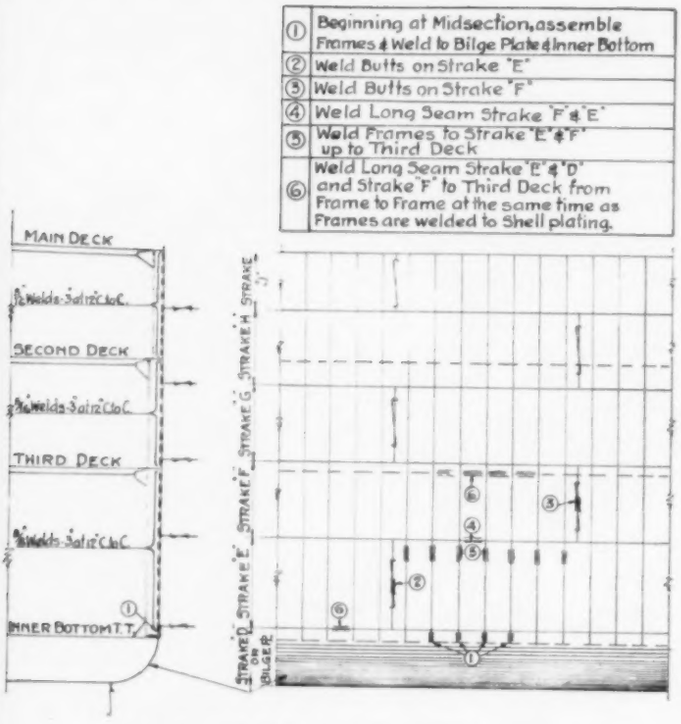

NOTE :- Fit-up and Weld Bilge Plate to Outer Bottom Floors and Tank Top
Proceed as follows.
1 Beginning with Midsection weld Floor to Bilge Plate. Weld Butts as you come to them
2 Weld Bilge Plate to Strake "C" (inside weld)
3 Weld overhead Bilge Plate to Tank Top
4 Weld overhead Bilge Plate to Strake "C"
5 Weld Tank Top to Bilge Plate
STRAKE "C"
STRAKE "D" OR BILGE PLATE
SEQUENCE FOR WELDING BILGE PLATING

Fig. 10

Fig. 11


① Beginning at Midsection, assemble Frames & Weld to Bilge Plate & Inner Bottom
② Weld Butts on Strake "E"
③ Weld Butts on Strake "F"
④ Weld Long Seam Strake "F" & "E"
⑤ Weld Frames to Strake "E" & "F" up to Third Deck
⑥ Weld Long Seam Strake "E" & "D" and Strake "F" to Third Deck from Frame to Frame at the same time as Frames are welded to Shell plating.
MAIN DECK
SECOND DECK
THIRD DECK
INNER BOTTOM T.T.
STRAKE "D" ON BILGE
STRAKE "E"
STRAKE "F"
STRAKE "G"
STRAKE "H"

SEQUENCE OF WELDING FOR SHELL PLATING

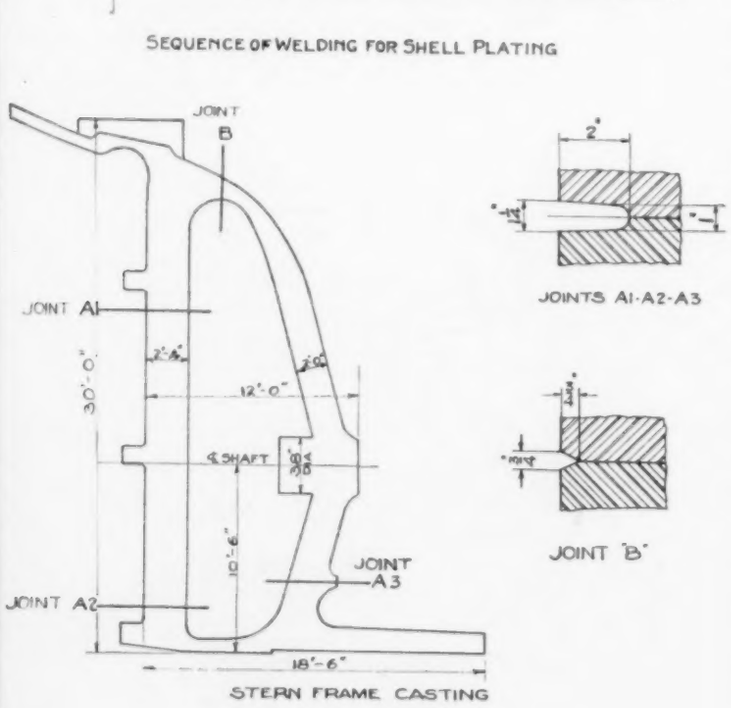


Fig. 12

frames, after which the entire assembly was lifted into place.

Details *C* show the frame and deck connections at the third, second and main decks. In each instance the side frames were cut to the proper length to fit between decks, and the deck panels were laid directly upon the frames; the frames were then welded solidly top and bottom to the decks, again with no reinforcing or clips except the brackets shown which attach to the deck beams and girders. The use of this particular detail for welded design provides, if desired, for a reduction in the size of the frames between the third and second decks, and again between the second and main decks. Not only is weight saved by cutting the frames and changing sizes, but it is believed that resting of the deck panels on top of the erected frames facilitates the erection and fairing up of the hull.

2.—Figure 7 is a cross section through the Diesel engine foundations and is probably the most complicated part of the hull requiring welding control while being erected (see Fig. 8). The foundation is an integral part of the double bottom, measuring forty-five feet in length, nearly nineteen feet in width and nine feet in height, and weighs, in place, more than sixty tons. It required more than four tons of welding rod to complete these foundations. These foundations provide a seating for two 2200 hp., Diesel engines and a reduction gear, and, after welding, must be fitted and ground to a tolerance of 0.001 inch. It can be readily understood that no distortion or deviation from dimensions is permissible.

A brief study of Fig. 7 will show the complexity of that portion of the foundation below the tank top and the manner in which the double bottom floors connect, and disclose the many intricate corners and connections to be welded. In order to visualize the structure in a completed state and to be certain that no point was overlooked in the development of a method and sequence of welding, it was necessary to build a small-scale model in which every detail was reproduced. This model was invaluable to the foremen and welders in working out their problems, particularly regarding the "Balanced Welding," and establishing the number of welders required to time the completion of the work to a given point.

This structure is subjected to considerable vibration and, with the complex welding involved, it was imperative that every possible means be exerted to eliminate all possible locked-up stresses. In several instances it was necessary to make full-sized celluloid models of joints and study the distribution of stresses with a polariscope, which resulted in the re-design of some joints or change in the method of welding same.

Practically all of the joints in the foundation structure were of the star type (see Fig. 9), which added materially in carrying out balanced welding, working two welders in opposite corners of the joint. Very few parts of the foundation were tacked securely together. Practically all of them were assembled in such a manner that they were able to move in relation to each other and the welding was always progressing toward the free end, or the part of the structure which was free to move. Each floor or frame was completely welded athwartship, working the welders in pairs on opposite sides (against each other) before moving to the next floor. At certain points, and under varying conditions, considerable distortion occurred temporarily. Measurements and levels were taken twice daily and disclosed a distortion of the foundation as much as five-eighths of an inch during the time the structure was being welded. Some apprehension was felt as to whether or not these discrepancies would adjust themselves at the proper time when the welding was completed, but after all welding on the foundations was completed, it was found that the welding did not produce any lift in the double bottom or any shrinkage not previously provided for. Figure 9 shows the welding sequence followed during the above-mentioned welding operations.

3. Welding Sequence to Prevent Shrinkage and Locked-Up Stresses.—Some concern was felt, and much consideration given to the development of a welding sequence that we hoped would control the shrinkage and stresses developed during the welding of:

(*a*) the double bottoms, including the bulkheads erected thereon,

(*b*) the shell plate butts and seams, together with the frames, transverse beams and deck beams that are welded to the shell plates.

The sequence of welding during the *erection* of the double bottom sections was as follows:

After the preassembled sections were placed upon the bottom shell plating, which was already on the blocks on the ship ways, and which had previously been welded into panels, using an automatic weld in and out, the welding together of the sections began, proceeding from midship forward and aft, making the transverse welds first, as the principal shrinkage occurred longitudinally due to the greater amount of welding necessary in the transverse seams and floors during erection. The sections were rather firmly attached to the bottom shell plating by slips, bolts or tacks, but in such a manner that the expansion joints were free, and so the shell plates could move or slip with the shrinkage occasioned by the transverse seam or floor welding.

Six transverse expansion joints consisting of a V groove with a buttstrap underneath were provided for in the tank tops. These expansion joints were not welded until the first bulkheads, hatch-end beams and girders, and third deck were in place, providing shade and an even temperature on the tank tops and bulkheads, then with that portion of the hull accurately dimensioned and partially faired up, the expansions were closed, insuring an accurate length of the hull and a level, even keel and bottom. What little transverse shrinkage could have occurred was provided for in the welding of one longitudinal seam adjacent to the side plate and extending the full length of the double bottom. There was no measurable deficiency in the length of the hull.

In general, the same procedure as outlined above was followed on the third, second and main decks with equal success, and at times the work was proceeding midship on the second or even main deck before the closing sequence welding was completed in the fore-peak bottom section or aft to the boss plate on the stern frame.

If the main body only, of the hull structure mentioned above, and exclusive of side shell plates and frames, there were 147 subassembly units, preassembled and welded in order to reduce shrinkage and stresses and each instance a welding sequence was developed to properly control the erection program.

Figure 10 shows the welding sequence used in connecting a bilge strake to the double bottom sections and side shell plates and Fig. 11 shows the welding sequence used in the erection of the side shell plates and deck connections above the double bottoms. At any time after two transverse bulkheads and included longitudinal bulkheads have been welded to the double bottom, no further shrinkage or distortion is liable to take place that prevents the accurate spacing and welding of the frames and shell plates within that area. At this stage of erection, the third deck is resting on the beams, girders and tops of the frames that extend from the margin plate to the under side of the third deck and two courses of plates are attached, by tack welds, to the frames.

Welding again begins amidships and progresses fore and aft, welding butts first, then frames to shell simultaneously with the welding of the seams between frames and the frame connections to decks. As soon as this sequence is completed between transverse bulkheads, the operation is repeated again between second and third decks and last between the main and second decks, forming a sort of pyramid with the welding proceeding amidships at the main deck while the welding is being closed up at the fore-peak and after-peak below the third deck.

The procedure followed as above brought the hull absolutely fair for vertical measurements between the main deck and keel and intermediate decks.

4. Expansion Joints and Their Function.—This is partially covered above, but it might be added that six transverse expansion joints, as previously described, were used on each deck which produced the general effect of erecting the hull in three horizontal layers after leaving the double bottom, and each layer, or deck, was allowed to work within prescribed limits until it was leveled and faired up, after which the expansion joints were welded. All welding around hatches and all heavy welding of deck reinforcements or other deck seams should be completed before closing the expansion joints. It is not to be expected that good fitting, accurate dimensioning and good welding are accomplished without some burning or chipping of an end or side of a panel, margin plate or bulkhead, particularly in the superstructure, of sections, margin plates or bulkheads.

5. Method of Welding Stern Casting and Adjacent Floors and Frames to Prevent Lifting.—The stern frame is of cast steel made in four sections (see Fig. 12), and after being normalized was delivered to the machine shop, laid out, and all joints machined as shown thereon. After being match marked, the casting was delivered to the ways and the bottom section was placed on the keel blocks and positioned, and the last keel plate connected and welded, using a $^3/_4$-inch fillet weld all around the edge of the keel plate (see Fig. 13). The original design called for the use of patch bolts through the after keel plate and shell plates for connecting them to the stern frame, and this to extend above the hub of the vessel. Plug welds were substituted and proved far more efficient for this work. We used a plug weld 1 x 2 inches, and the same spacing was maintained as was intended for the patch bolts. This type of oblong plug weld, if properly made, does not lend itself quite so readily to shrinkage cracks as a smaller circular plug weld. After the bottom

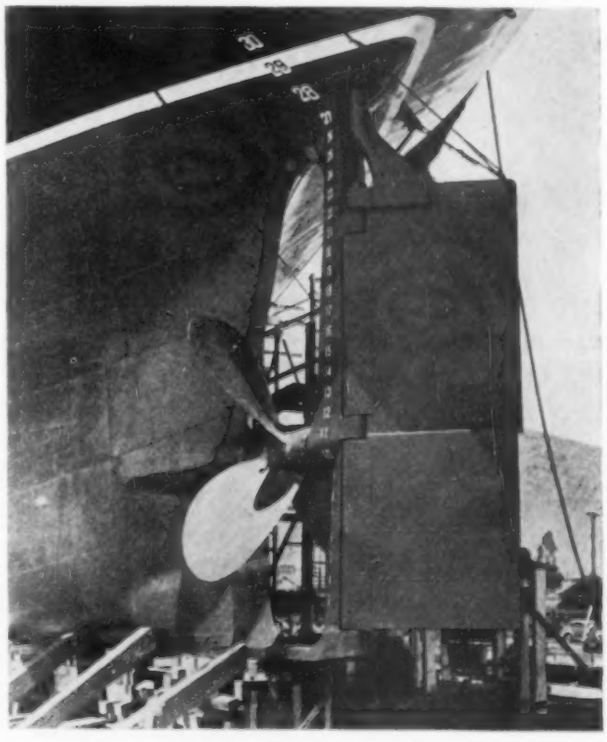
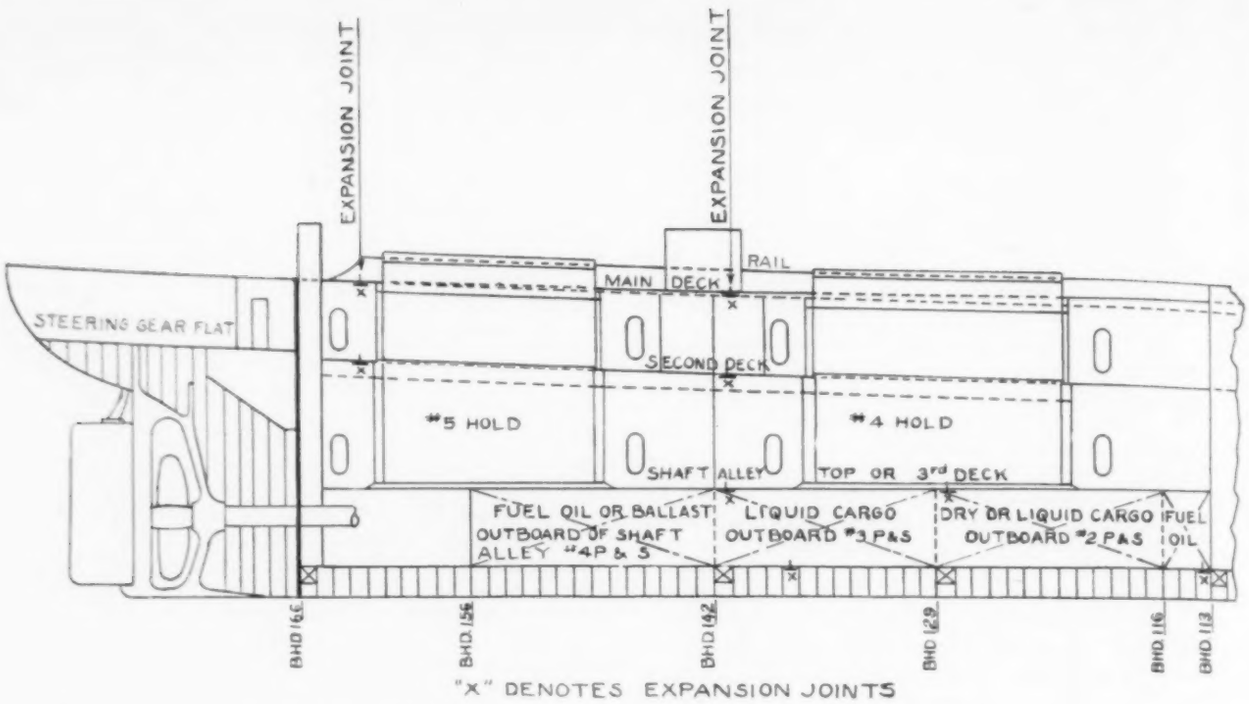


Fig. 13



INBOARD ELEVATION ABAFT MACHINERY SPACE

Fig. 14

section of the casting was welded in place, the remaining three sections of the casting were erected, faired up and connected to the ship structure and the joints were then ready for welding.

The procedure of welding was carefully worked out so as to prevent excessive shrinkage and distortion of the casting, or alignment of the frame. Each seam was preheated to about 300° F. on each side of the seam before welding started. Two welders were working opposite each other using the same size electrode and the same heat. The welding on each joint, in the order stated above, proceeded continuously without interruption until

Table 1

	No. of Welders	No. of Hours	Welding Rod, Lb. Gross	Net
Joint *A*1	2	19	106	84
Joint *A*2	4	20	100	78
Joint *A*3			88	70
Joint *B*	1	8	19	15

the joint was completely welded. Each pass was thoroughly cleaned and lightly peened to relieve strain. Table 1 shows the time consumed in the welding of the joints, also the amount of welding rod used.

The welding of the stern frame "in position" and not "in the flat" was not only for the purpose of allowing for the handling of smaller weights during the assembly of the casting into the ship structure, but also to provide a balanced position for welding, which was considered quite important. With the frame in place, all seams with the exception of seam *B* are in the same plane and, therefore, all can be welded in the same position on both sides of the casting with the same heat, keeping the joint evenly heated; and, therefore, equalizing the shrinkage on both sides of the casting. In the method described above on four stern frames, shrinkage on the seams never exceeded $^1/_{64}$ of an inch, and no trouble was experienced with distorting alignment of the parts.

We had been cautioned by many individuals regarding the possibility and extent to which the stern or entire after-peak section might rise, due to the shrinkage in the welds, which are somewhat concentrated in that area. We were advised that this rise might exceed $2^1/_2$ inches. Beyond the customary study of the matter, we made only one concession to humor the situation; we set the stern casting about $^5/_8$ of an inch below the line of the bottom of the keel. During the welding in the deep tanks forward of bulkhead No. 166 (see Fig. 14), this rise began to develop, and as the welding of the floors, frames and shell plates aft of bulkhead No. 166 proceeded upward from the boss plate to the stearing gear flat, the rise continued until it exceeded the tolerance we had provided. It was forecast that the greatest acceleration in rise would take place during the very considerable amount of transverse welding in an area centering around the steering gear flat aft of bulkhead No. 166 extending to the stern frame casting and upward to the main deck. Assuming a line half way between the keel and main deck, aft of bulkhead No. 166, the upper half of the hull probably has eight times as much "in place" welding as the lower half of the hull. The forecast was partially correct, as, over a three- or four-day period of intensive welding in this area, the rise accelerated to more than $^5/_{16}$ of an inch per day; but, thereafter, no further measurable movement took place. The total rise amounted to $1^5/_8$ inches, not all of which, however, was attributed to welding shrinkage. We were told that a rise of $^5/_8$ of an inch in a riveted hull, due to the sag or buckling amidships, is not uncommon. In the more recently welded hulls, improved technique has materially lessened this rise.

During a two-week period while the welding in this area was progressing, levels and lines were run morning, noon and night, and the resulting records of the movements of the stern casting were truly puzzling. A point located on the stern casting was constantly on the move, developing a two-week chart not unlike the journeys of a fly trapped inside a $1^1/_2$-inch diameter

ball. Sunshine, fogs and cold winds, as well as temperature changes day and night, probably caused more movement than the welding. Suffice to say, however, that before launching the first hull, the rise in the stern was not sufficient to cause comment, it amounted to a strong inch (depending on who measured it) above the line of the bottom of the keel, but even less when measured from a base constituting the *average* line of the bottom of the keel.

Inasmuch as time is short, and a motion picture showing some of the welding details is to follow this paper, we will eliminate the discussion on the welding of the light superstructure. Therefore, in conclusion, we would like to state that the research work carried on in the past and being carried on at the present by the AMERICAN WELDING SOCIETY and its affiliated societies has revealed a vast store of welding information carefully compiled and built upon a solid foundation of experience; all of which insures the steady progress of design and construction of welded hulls to a point where it is to be hoped the desirability of doing work in any other way than welded will soon be considered obsolete.

How to Make Sprockets by Hand-Cutting

By J. M. Dulaney*

A PIPE line contractor has developed a fairly simple method for the fabrication of drive sprockets which should prove of interest to any shop which has occasion to require replacement sprockets for its machinery and equipment.

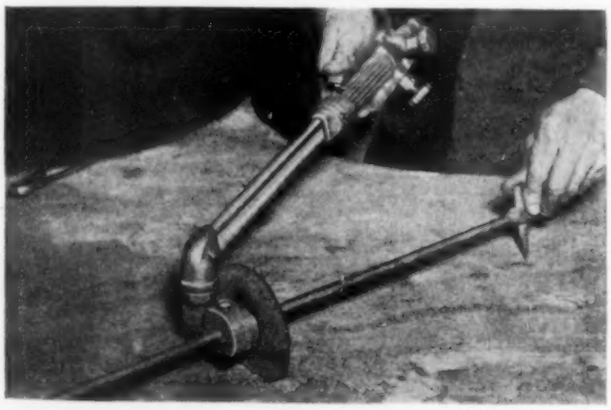


Fig. 1—This Homemade Radius Rod Makes It Easy to Cut the Outside Diameter of the Sprocket Blanks

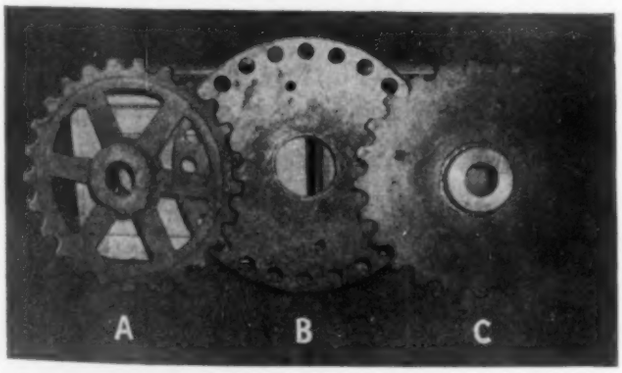


Fig. 2 (Left)—Cast Steel Sprocket. (Center) Sprocket During Fabrication Showing Holes Drilled for Sprocket Teeth. (Right) Completed Sprocket

* The Linde Air Products Co., Houston, Texas.

These sprockets are part of the drive unit on ditching machines. Formerly steel castings were purchased, but these sprang out of shape due to the severe service to which they were subjected and had to be replaced frequently. Now, the sprockets are fabricated in the maintenance shop out of $1^1/_4$-in. steel plate. Although the fabricated sprockets cost about the same as the cast sprockets, they have the decided advantages of being stronger and lasting longer.

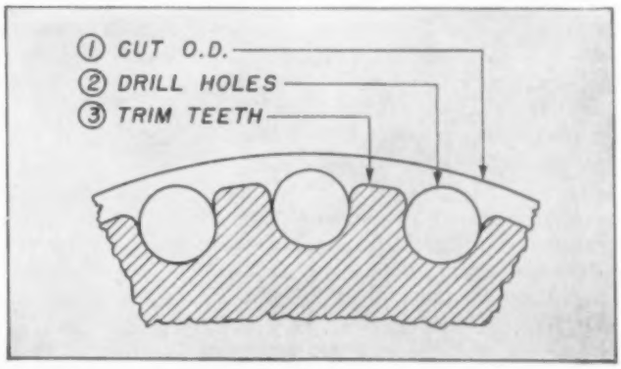


Fig. 3—The Three Steps in Shaping the Sprocket Blank and Teeth Are Shown in This Sketch

The first step is to cut the outside diameter of the sprocket. This is done with a hand-cutting blowpipe, using a homemade radius rod as a guide. The radius rod, as shown in Fig. 1, consists of a round bar to which are attached a holder for the blowpipe nozzle, a riding wheel and a center point.

The next step is to drill equally spaced holes around the circumference of the sprocket blank, as shown in Fig. 2. Then, using the hand-cutting blowpipe, the metal between the holes and the outside diameter is cut away and the teeth are trimmed to shape, as shown in the sketch Fig. 3. The final operation is to weld a hub to the center of the sprocket.

Power Supply for Resistance-Welding Machines—III

Factory Wiring for Resistance Welders

AIEE COMMITTEE ON ELECTRIC WELDING
Subcommittee on Power Supply for Welding Operations

Purpose of Report

AN adequate power supply is one of the requisites of present-day, high-production resistance welding. A major part of the power supply system of any industrial plant lies within the plant itself and consists of the plant wiring and transformer substations. It is the purpose of this report to show how to properly lay out such a plant distribution system for serving welders. Much of the fundamental data included in the tables and charts is not new but is included in order that the layout engineer will have complete information available in one compact report and will not have to refer to various articles and handbooks, copies of which may not be readily available.

General Considerations

The first report of this series, "Guide to Good Electrical Performance of Resistance Welding Machines," pointed out the need for keeping welder kilovolt-ampere inputs as low as possible for given welding current outputs, and the next step consists of providing adequate supply facilities for handling these inputs. Because of the high currents involved, transformers should be located as close to the welders as possible, keeping the secondary bus and feeder runs short. In many cases it will be found advantageous to use transformers containing a liquid that will not burn rather than oil in order that they can be located adjacent to the welding machines rather than at some relatively remote outdoor or vault location. With the load power factor generally falling between 20 and 40 per cent, it is essential that the reactance of the power supply system be kept at a minimum. Generous copper cross section in welding feeders is usually less important than proper spacing and arrangement of the conductors for minimum reactance.

The first question to be answered is: "For what voltage drop shall the supply system be designed?" No specific answer can be given which will apply to all cases and, as pointed out in the preceding report, satisfactory results may be obtained with 15 per cent regulation in one case and 5 per cent may be too much in another. However, in general with the usual class of production resistance welding involving low and medium carbon steels, satisfactory welding will result if the voltage drop to a point on the supply system common to two or more machines does not exceed ten per cent for the largest machine of the group. This statement is based on the assumption that there are relatively few large machines in the group being served (say, not over five or ten machines) and that, while two of them may occasionally operate at the same time, the chances of three or more operating together is extremely remote. Thus, if the machines are adjusted for perfect welding with a ten per cent voltage drop in their supply circuit, the welds will still be good when two machines operate together causing nearly 20 per cent drop. If three or more happen to hit together, poor welds or rejects may result. Care should be exercised in adjusting machines, with the setting made under highest voltage and maximum current conditions, just short of burning the weld so that under minimum voltage conditions a good weld will still result.

Experience indicates that this general rule of ten per cent drop for the largest machine will result in a good workable installation in most cases although it should be realized there will be exceptions. The procedure outlined in the following sections will follow the ten-per-cent rule with some indication as to how to determine those installations which will require special consideration as exceptions to the general rule.

Where even less than ten per cent regulation can be provided at about equal cost, such as obtained by close spacing of feeders, this obviously should be done. The ten-per-cent figure is set only as an approximate allowable upper limit and any improvement below this value is all to the good and makes for that much better welding conditions.

Interlocking can be resorted to under some conditions to insure not more than one or two machines operating at the same time. This is an inexpensive practice where only a few large machines are involved and in most cases production speed is not materially reduced.

While the current-carrying capacity of the supply feeders and transformers must receive consideration, if provision is made to keep the voltage drop within the necessary limits, there usually will be sufficient attendant thermal or carrying capacity.

Voltage Drop

For convenience, the supply system can be broken up into three parts:

1. High-voltage power supply system (2,400 volts or higher)
2. Step-down transformer bank
3. Low-voltage bus or feeder (240 or 480 volts)

High-Voltage Power Supply System

The high-voltage power supply system in most cases is the power company's service to the plant. Where the plant generates its own power, it is typified by the generator bus system. In most cases very little can be done toward reducing the voltage drop in the high-voltage power supply system at a cost commensurate with the expenditure needed for the same percentage reduction in the low-voltage system.

In the case of service from a power company, the amount of voltage drop for a given welding load is dependent upon the relative location of the industrial plant with respect to the power company's large distribution substations as well as generating stations. If the plant is in an established industrial area served by large substations and not too far from large generating stations, the voltage drop in the high-voltage system will be a negligible factor. However, if the plant has been located in a rural or small-town area far removed from the power company's main generating stations, as is becoming more common under the present-day trend toward decentralization of industry in the search for low manufacturing costs and reduced taxes, the high-voltage system regulation may loom up as a very troublesome factor. Any plant in which resistance welding is extensively used should carefully investigate this matter of high-voltage system regulation when contemplating moving the plant to any other location with less adequate power facilities for welding.

In the case of private power generation,

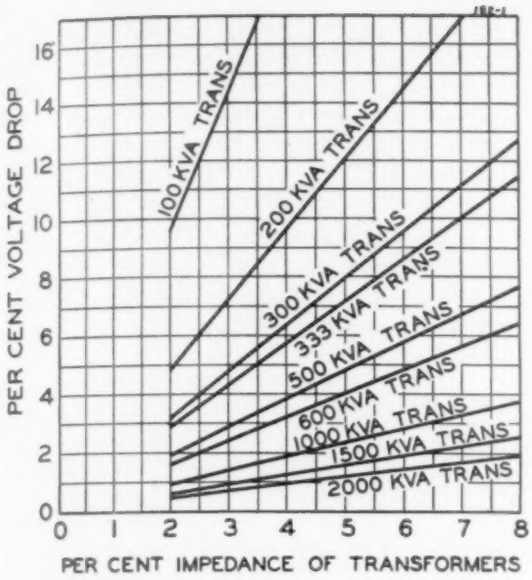


Figure 1. Welding supply—transformer regulation

Per cent voltage drop per 1,000 amperes of 30 per cent power factor, single-phase welding current

1. For 480-volt, single-phase transformer bank, use chart values of per cent voltage drop
2. For 480-volt, three-phase transformer bank, multiply per cent voltage drop by 2
3. For 240-volt, single-phase transformer bank, multiply per cent voltage drop by 1/2
4. For 240-volt, three-phase transformer bank, use chart values of per cent voltage drop

the voltage drop at the generator bus will be inversely proportional to the total rating of generators feeding the bus. The small and moderately sized plant will experience considerable difficulty in handling any but the smaller-sized welding machines without encountering lamp flicker problems in their plant and office lighting.

The first step in designing the plant wiring and bus layout for welding is to determine the high-voltage system regulation. This can be obtained from the local power company by giving them the maximum kilovolt-amperes and power factor that the largest machine will draw from the power system. Subtract the figure obtained from the total allowable ten per cent and the remainder is that which can be allowed in the step-down bank and secondary or low-voltage bus system. For instance, assume the largest welder is rated 300 kva and will deliver a maximum welding current of 100,000 amperes with a high secondary open circuit voltage of 8 volts. The approximate maximum kilovolt-ampere input (neglecting exciting current) is $(100{,}000 \times 8)/1{,}000 = 800$ kva. From the power company representative it is learned that 800 kva at an estimated 30 per cent power factor will cause four per cent drop in the power company service to the transformer bank at the customer. This subtracted from ten per cent leaves six per cent which can be used up in the step-down transformers and low-voltage bus system.

Step-Down Transformer Bank

On the assumption that the remaining allowable six per cent drop can be divided about equally between the step-down transformer bank and low-voltage bus system, it is necessary to select the proper size transformer which will limit the drop to about three per cent.

Welders can either be served from a single-phase transformer bank or a three-phase bank, and where the welding load is large enough to justify a separate transformer bank for welding load only, it will be found advantageous and more economical of capacity to use a single-phase system. The load is single phase and it will remain single phase no matter how the transformers ahead of it are connected. Sometimes it is desirable to spread the individual single-phase loads over the three-phase wires for more economical utilization of the supply lines, but unless there are large numbers of machines connected, the necessity for balancing the load is not important. When there are many machines, they are usually scattered around in different parts of the plant so that several step-down banks become necessary at different locations. In this case individual single-phase banks can be connected to separate phases and thus bring about some semblance of balance on the supply wires.

A given kva of single-phase load fed from a three-phase transformer bank will cause just twice as much transformer voltage drop as the same kva load fed from the same capacity in transformers connected as a single-phase bank. It is thus obvious that, where the transformer voltage drop must be kept at a minimum, it is highly desirable and more economical to use single-phase, step-down banks of transformers.

In case the welding load is relatively small in comparison with the motor and other power load of the plant, it can readily be served from the same three-phase bank serving the power load. Individual plant and service conditions thus dictate whether single-phase or three-phase banks are the logical selection. Irrespective of whether the welding load is served from single-phase transformers or from three-phase transformers in combination with the motor

Figure 2. Welding supply—wire feeder regulation

Per cent voltage drop per 1,000 amperes of 30 per cent power factor, single-phase welding current

1. For 480-volt feeder, use chart values of per cent voltage drop
2. For 240-volt feeder, multiply per cent voltage drop by 2

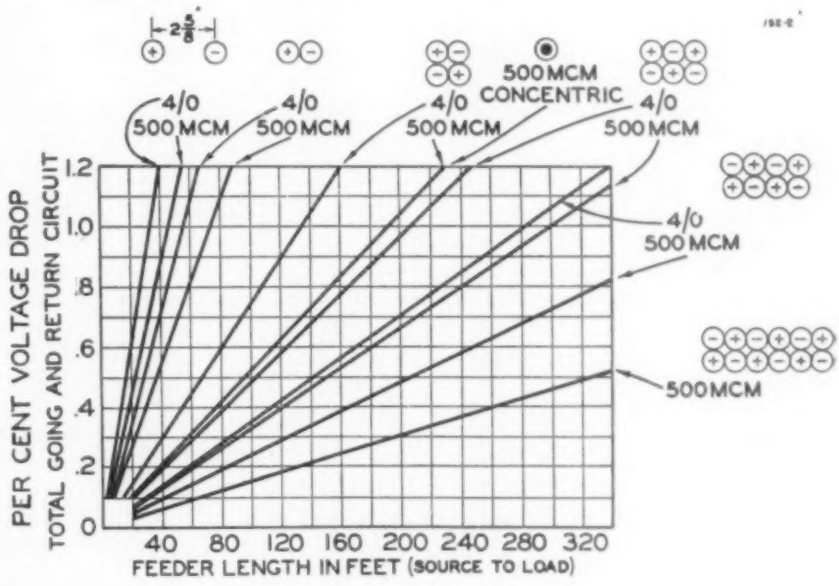


Figure 3. Welding supply—bus regulation

Per cent voltage drop per 1,000 amperes of 30 per cent power factor, single-phase welding current

1. For 480-volt bus, use chart values of per cent voltage drop
2. For 240-volt bus, multiply per cent voltage drop by 2

and power load, the lighting load should usually be handled separately in order to prevent flicker difficulties.

Figure 1 shows per cent voltage drop per 1,000 amperes of 30 per cent power factor welding current through transformer banks of different sizes and impedance. Plant practice may determine the size and impedance of individual transformers and the number of units to connect in parallel can be determined from the chart. For instance, assume that 300-kva, 3½-per-cent-impedance transformers are used by this particular plant in its step-down banks. A load of 800 kva represents 1,670 amperes at 480 volts. From figure 1: 1,670 amperes through a 300-kva, 3½-per-cent-impedance transformer causes 1.67 times 5.6 per cent = 9.4 per cent = voltage drop. Therefore, three transformers in parallel would have to be used to stay within the predetermined limit of three per cent drop. In some cases a special low-impedance transformer may be economically justified. For example, if a two-per-cent-impedance transformer is purchased, the nearest size transformer would be 500 kva which would allow 3.2 per cent drop. This might be cheaper than the three 300-kva transformers but would have the definite disadvantage of not being usable interchangeably at other plant locations. If a plant has sufficient welding load, it sometimes pays to standardize on special low-impedance transformers for welding only and not attempt to make them interchangeable with transformers used in power and lighting banks.

Low-Voltage Bus or Feeder

There is now only three per cent remaining out of the original allotted ten per cent drop. It is found that the bus or feeder must be 300 feet in length to reach the two machines located farthest from the transformer bank.

Figures 2 and 3 show the per cent voltage drop per 1,000 amperes of 30 per cent power factor welding current for different types and sizes of bus and wire construction. Figure 2 is for various wire arrangements and figure 3 for different bus arrangements. Some plant engineers prefer one class of construction and some the other. The bus can be made up on the job or it can be purchased, prefabricated in unit lengths either with or without enclosures.

Usually if the welders are in a fairly compact group but at some appreciable distance from the transformer bank, some arrangement of wire feeder works out to advantage. However, where the machines are scattered and frequent taps must be made to the supply wires or bus, a bus system is perhaps more advantageous in that frequent connections to it are readily made.

From the charts it is found that two 500,000-circ-mil wires per leg in conduit would handle 800 kva with 2.6 per cent drop at the 300-foot distance. (800 kva = 1,670 amperes. From the chart the drop for 150 feet = 0.78 per cent; for 300 feet and 1,670 amperes the voltage drop equals 0.78 per cent times 2 times 1.67 = 2.6 per cent.) For the bus construction a bus consisting of two ¼-inch by 4-inch copper bars on one-inch centers would be suitable from a voltage-drop standpoint.

It is possible that either of these selections may have sufficient current-carrying capacity for handling the equivalent steady or thermal load of the group of welders. However, if it is found that more carrying capacity is needed, other configurations are shown with equal or better voltage-drop characteristics.

Equivalent Continuous Thermal Loading

There are several ways in which the equivalent continuous thermal loading of a group of welders can be determined. It might be reasoned that the quickest and simplest method would be to add the name-plate kilovolt-ampere ratings of the individual welding transformers, and then apply a suitable diversity factor for group operation. The welding transformers are rated on a 50-per-cent duty-cycle basis and, consequently, if all of the machines are operated continuously right up to the thermal capacity of their transformers, the equivalent continuous thermal loading would be $\sqrt{0.50}$ or 70.7 per cent of the sum of the name plate ratings. Thus, if there were ten 300-kva welders, the supply system on this basis should have a carrying capacity of 70.7 per cent of 3,000 kva, or 2,100 kva less the diversity factor correction.

In actual practice, however, most machines, except perhaps some seam welders, operate well below their maximum thermal capacity, because the size of transformer in the machine is dictated by the required welding current output rather than by thermal considerations.

Tests of many installations show that the values given in table I are more clearly representative of actual field conditions. Thus, if the machines are predominately spot, projection, or flash welders, a supply system with a rating of 15 per cent of the sum of the name-plate ratings of the machines would, in most cases, be adequate. Thus, taking the ten 300-kva welders, the supply system should be good for about 15 per cent of 3,000 kva, or 450 kva.

Table I. Equivalent Continuous Loading of Typical Welding Machine Installations

Types of Welding	Equivalent Continuous Load Expressed in Per Cent of Sum of Name-Plate Ratings
Spot, projection, flash	5 to 10 (most installations) 10 to 20 (very few installations)
Hydromatic, butt	10 to 20
Seam	25 to 70

A second check should be made based upon the actual kilovolt-ampere loads of the welders and their operating duty cycles. Assume that each of the ten 300-kva machines was on a production schedule of 100 welds per hour with maximum loads of 800 kva for 10 cycles per weld. The corresponding duty cycle of each machine is: $(10\times100)/(60\times60\times60)=0.46$ per cent. The equivalent continuous load corresponding with 800 kva at 0.46 per cent duty cycle is: $\sqrt{0.0046}\times800$ kva $=54$ kva. For the total of ten machines, if all were operating at peak production, the equivalent kilovolt-amperes would be $10\times54=540$ kva.

The selection of three 300-kva transformers on the basis of voltage-drop considerations is thus perfectly safe from the standpoint of current-carrying capacity. The 500-kva, 2-per-cent-impedance transformer might be just a little small from a thermal capacity standpoint for ten machines in peak production but, with the usual diversity of group operation, should be adequate.

Tables II and III show the equivalent carrying capacity in continuous amperes of the various types of bus and wire arrangements commonly used. The ampere load corresponding with an equivalent continuous thermal load of 500 kva at 480 volts is approximately 1,000 amperes. Thus, the wire construction previously selected on the basis of voltage drop is not large enough from the standpoint of current-carrying capacity. A wire grouping consisting of four 500,000-circ-mil wires per leg (item 11, table II) is rated about 1,000 amperes and should be adequate for the job. This wire arrangement will have only 1.2 per cent voltage drop for an 800-kva load swing, thus being well within the three per cent allowed.

It should be emphasized here that the current-carrying capacities given in table II for six or more total wires in a trough or raceway enclosure are estimated values only and while considered to be reasonable approximations, they are subject to change whenever verifying test data become available. The current-carrying capacities for most of the bus arrangements in table III are extrapolated from test data of similar configurations both in the open and in metal enclosures and should, consequently, be reasonably accurate although here again, actual test data would be welcomed by the industry.

Similarly, table III shows several types of bus construction well within the three-per-cent voltage-drop allowance which will have adequate carrying capacity. The original selection of one $^1/_4$-inch by 4-inch bar per leg on one-inch centers would be adequate if mounted in the open. However, most bus installations will require enclosures and on this basis the selection would be between the heavier current-carrying busses having drops of less than three per cent.

Chance of Simultaneous Welds

Designing for a total of ten per cent voltage drop for the operation of the largest machine produces satisfactory welding conditions only when three or more machines do not happen to operate at the same instant. Based upon the general law of averages, the expectancy of simultaneous welds can be readily calculated. For the sake of simplicity, it is assumed that even if only a single cycle of one weld overlaps another, this would constitute a simultaneous weld. Obviously, except for very short-time welds (two to three cycles), a single cycle overlap should not prove serious and this assumption thus introduces a considerable factor of safety.

T = total time per weld per machine, including "off" and loading time as well as actual weld time

t = actual weld time per machine

E = number of machines

$\frac{T}{tE}\times\frac{T}{t(E-1)}$ = interval in terms of number of welds between operations in which *two* machines make a weld at the same time including any slight overlapping of actual welding time

$\frac{T}{tE}\times\frac{T}{t(E-1)}\times\frac{T}{t(E-2)}$ = interval in terms of number of welds between operations in which *three* machines make a weld at the same time including any slight overlapping of welding time

In usual production welding if rejects due to simultaneous welds do not occur oftener than once per hour, which would be one weld out of every 5,000 or 10,000, conditions would probably be considered highly satisfactory. Table IV shows various combinations of machines, welding time, hourly production, and corresponding interval of time between expected simultaneous welds. For instance, 20 machines with three-cycle welding can produce 200 welds per hour per machine with an expectancy of three simultaneous welds and three rejects every 1.7 hours. With the production stepped up to 300 welds per hour per machine, the resultant expected interference might be such that it would be desirable to either split the

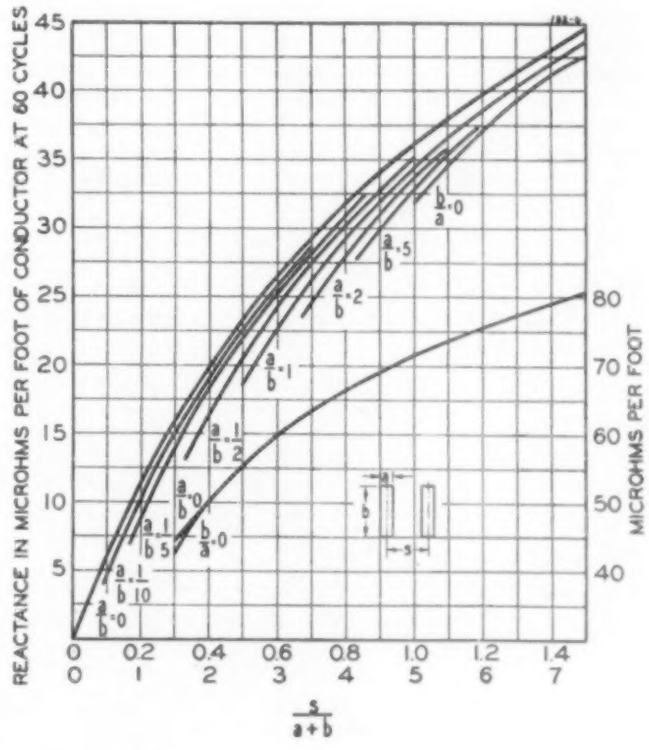


Figure 4. Reactance of strap conductors at 60 cycles

Table II. Welding Supply—Wire Feeder Data. Calculated Data Per 100 Feet of Distance From Source to Load (200 Feet of Circuit)

Item	Wires Per Leg	Spacing (See Figure 2)	Size	Area Square Inches	Approximate Current-Carrying Capacity Copper 60 Deg C Ambient 30 Deg C (Amperes).	Weight (Pounds)	D-C Resistance 25 Deg C (Ohms)	Reactance (Ohms)	Voltage Drop Per 1,000 Amperes 30 Per Cent Power Factor	
									Volts	Per Cent at 480 Volts
1	1	2⅝-inch centers	4/0	0.166	225[1]	131	0.01	0.012	14.3	2.98
2	1	2⅝-inch centers	500,000 circ-mil	0.393	400[1]	308	0.0043	0.0098	10.7	2.22
3	1	Wires laced together	4/0	0.166	210[2]	131	0.01	0.0059	8.72	1.82
4	1	" " "	500,000 circ-mil	0.393	350[2]	308	0.0043	0.0056	6.63	1.38
5	2	" " "	4/0	0.332	400[2]	261	0.0051	0.0022	3.63	0.76
6	1	Concentric cable	500,000 circ-mil	0.393	300[4]	308	0.0043	0.0013	2.53	0.53
7	2	Wires laced together	500,000 circ-mil	0.786	650[2]	616	0.0022	0.002	2.54	0.53
8	3	" " "	4/0	0.498	500[3]	392	0.0034	0.0014	2.36	0.49
9	4	" " "	4/0	0.664	600[3]	522	0.0026	0.001	1.72	0.36
10	3	" " "	500,000 circ-mil	1.18	850[3]	925	0.0014	0.0013	1.63	0.34
11	4	" " "	500,000 circ-mil	1.58	1,000[3]	1,230	0.0011	0.00089	1.17	0.24
12	6	" " "	500,000 circ-mil	2.36	1,300[3]	1,850	0.00072	0.0006	0.79	0.17

Notes: 1. Code limit.
2. In conduit, wires laced together.
3. In trough, wires laced together (estimated values—no test data known).
4. Reactance is slightly higher when wire is in magnetic trough or conduit.
5. In conduit (estimated value—no test data known).

machines into two groups or design for a five per cent instead of ten per cent voltage drop in the supply system.

The last column shows total time divided by the actual weld time of all large machines on the bus. As long as this value is greater than 10 or 20, satisfactory welding conditions should generally result on a supply system with ten per cent voltage drop, as the chances of three simultaneous welds occurring oftener than once per hour is rather remote. (For exceptions see last paragraph.) It should be remembered that these considerations apply only to the large machines. Innumerable small machines can be served from the same transformer bank and bus system along with the five or ten large machines, upon which the distribution system design is based, without any further consideration except that of thermal carrying capacity of the system.

It might not be amiss in this connection to point out another frequently encountered cause of poor welding in addition to that of excessive voltage regulation. There is a tendency on the part of many users of welding equipment to increase the welding speeds far beyond the capacity of the equipment to make good welds. As a result, a certain percentage of such welds are inferior. The designer then specifies a greater number of welds in an attempt to assure himself of a sufficient number of good welds to produce a satisfactory joint. The production department must then make these welds at an even faster rate of speed to maintain costs, resulting in an even greater number of inferior welds.

This vicious circle of events can be eliminated by insistence upon good welding throughout, resulting in fewer welds per joint, which in turn permits welding speeds commensurate with good welding. This results in better voltage regulation by reducing the chances of simultaneous or interfering welds on any given feeder line.

There may be some classes of welding where every weld must be perfect and there must be no chance of even a few undetected poor welds passing inspection. In these cases it may be desirable to design for closer regulation. However, even under these conditions, the extra investment needed for reduced regulation should be balanced against the cost of necessary recorders and indicators for detecting welds made under improper conditions of voltage, current, and time. It might be more economical to invest in the recorders and indicators than in excessive feeder and transformer capacity which would only be needed once or twice a day when three or more machines might happen to hit together.

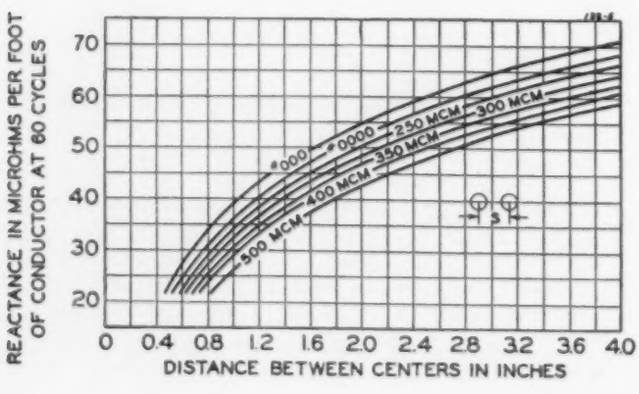


Figure 5. Reactance of standard strand cables at 60 cycles

Example. Ten 300-kva machines, each machine producing 100 welds per hour of 10 cycles duration each:

$$T = \frac{60 \times 60 \times 60}{100} = 2{,}160 \text{ cycles}$$

$t = 10$ cycles

$E = 10$ machines

$$\frac{T}{tE} \times \frac{T}{t(E-1)} = \frac{2{,}160}{10 \times 10} \times \frac{2{,}160}{10 \times 9} = 518 \text{ welds}$$

between operations in which *two* machines make a weld at the same time

Total output = 1,000 per hour

Two welds together every $(518 \times 60)/1{,}000 = 31$ minutes

$$\frac{T}{tE} \times \frac{T}{t(E-1)} \times \frac{T}{t(E-2)} = \frac{2{,}160}{10 \times 10} \times \frac{2{,}160}{10 \times 9} \times \frac{2{,}160}{10 \times 8} = 14{,}000 \text{ welds}$$

beween operations in which *three* machines make a weld at the same time

Three welds together every $14{,}000/1{,}000 = 14$ hours

Total time divided by weld time of all welders $= (60 \times 60 \times 60)/(10 \times 10 \times 100) = 21.6$

Interlaced Bus Calculations

The reactance values of the various wire groupings and bus-bar configurations shown in figures 2 and 3 and in tables II

and III were calculated by means of the following short-cut method, utilizing the charts of reactance for a pair of conductors (either for conductors, figure 4, or standard strand cables, figure 5).[1] In this way it is possible to calculate the reactance of an interlaced bus or cable system with a reasonable degree of accuracy in a few minutes, as compared with the more laborious method based upon the fundamental relations of mutual and self-inductance which at best requires several hours.

This short-cut method of calculation is incorporated as part of this report in order that quick calculations can be made for other wire or bus configurations than those shown in the tables.

The basic methods and curves used here are not new, but were published in U. S. Bureau of Standards Scientific Paper No. 281 by Francis B. Silsbee, and also in *The Electric Journal* of June 1919 in an article entitled "Reactance Values for Rectangular Conductors" by H. B. Dwight. However, it was felt desirable to bring together all of the necessary data for the calculation of welder bus reactance and to show by actual examples the use of these data for the calculation of interlaced conductors.

The more general types of welder busses which are commonly used are: (1) four or more stranded insulated conductors interlaced and clamped together, (2) interlaced copper bars, and (3) concentric tubes. Figures 4 and 5 show the total reactance, self minus mutual, between two conductors. The same curves can be used in the following manner when more than two conductors are involved and there is an even number of conductors. Consider an interlaced bus consisting of six conductors, three going and three returning, as shown in item 15, table III, arranged as follows:

(+1) (−4) (+2) (−5) (+3) (−6)

Since the average drop of the going circuit equals the average drop of the return circuit, it is only necessary to find the drop in the going circuit and multiply it by two to determine the total circuit drop. If, as a first approximation, it is assumed that the current divides evenly between all of the going conductors, the reactance of any going conductor is the sum of the reactances of all the return conductors to the given going conductor minus the reactance of the remaining two going conductors to the given going conductor. Dividing the sum of the reactances of the going conductors by three gives the average going reactance per conductor and dividing this average by three (since it is assumed that only one-third of the current went through each conductor) gives the going circuit reactance. Multiplying this value by two gives the total circuit (going plus return) reactance.

The reactance of each going conductor can be written as follows:

$$X_1 = X_{14} + X_{15} + X_{16} - X_{12} - X_{13}$$
$$X_2 = X_{24} + X_{25} + X_{26} - X_{21} - X_{23}$$
$$X_3 = X_{34} + X_{35} + X_{36} - X_{31} - X_{32}$$

The total circuit reactance (going plus return) is:

$$X_T = \frac{2}{9}(X_1 + X_2 + X_3)$$

It should be pointed out that, although this method is approximate, it is accurate within ten per cent which is good enough for most practical calculations.

Numerical Example 1. Determine the reactance of an interlaced bus 1,000 feet long, consisting of 1/4-inch by 4-inch copper bars spaced one-inch center-to-center as shown in table III, item 15. The distance between the center lines of each conductor and all of the other conductors should be calculated and the reactances corresponding to these distances should be obtained from figure 4.

For example, the distance between the center lines of conductors 1 and 4 is $1'' \times \frac{S}{a+b} = \frac{1''}{1/4'' + 4''} = 0.235$ and the corresponding reactance is 0.0125 ohm per 1,000 feet. The remaining reactances can be found in a similar manner.

$$X_1 = 0.0125 + 0.0290 + 0.0392 - 0.0220 - 0.0347 = 0.0240$$
$$X_2 = 0.0125 + 0.0125 + 0.0290 - 0.0220 - 0.0220 = 0.0100$$
$$X_3 = 0.0290 + 0.0125 + 0.0125 - 0.0347 - 0.0125 = -0.0027$$
$$X_T = \frac{2}{9}(X_1 + X_2 + X_3) = \frac{2}{9}(0.0249 + 0.0100 - 0.0027) = 0.00696 \text{ ohm (going and return)}$$

The same method can be used on stranded cables, except that the reactance values are taken from figure 5.

Numerical Example 2. Determine the re-

Table III. Welding Supply—Bus-Bar and Tubing Data. Calculated Data Per 100 Feet of Distance From Source to Load (200 Feet of Circuit)

Item	Bars Per Leg	Spacing (See Figure 3)	Size (Inches)	Area Square Inches	Approximate Current-Carrying Capacity 35-Deg C Rise (Amperes) Open	Housing[2]	Weight (Pounds)	D-C Resistance 25 Deg C (Ohms)	Reactance (Ohms)[3]	Voltage Drop Per 1,000 Amperes 30 Per Cent Power Factor Volts	Per Cent at 480 Volts
1	1	8" centers	1/4x2	0.5	750	490	386	0.0033	0.0126	13.0	2.71
2	1	8" "	1/4x4	1.0	1,400	950	772	0.0017	0.0098	9.84	2.05
3	1	2 1/4" centers	1/4x2	0.5	750	490	386	0.0033	0.0072	7.86	1.64
4	1	2 1/4" centers	1/4x4	1.0	1,400	950	772	0.0017	0.0048	5.07	1.06
5	1	1" centers	1/4x2	0.5	720	450	386	0.0033	0.0041	4.91	1.02
6	2	3" centers interlaced	1/4x2	1.0	1,400	950	772	0.0017	0.0039	4.19	0.87
7	1	1" centers	1/4x4	1.0	1,370	900	772	0.0017	0.0025	2.88	0.60
8	2x2	3" centers interlaced	1/4x3	3.0	3,600	2,600[4]	2,315	0.00056	0.0028	2.84	0.59
9	2	3" " "	1/4x4	2.0	2,600	1,800[4]	1,544	0.00084	0.0026	2.73	0.57
10	2	1" " "	1/4x2	1.0	1,350	870	772	0.0017	0.0018	2.25	0.47
11	1	1/2" centers	1/4x4	1.0	1,370	900	772	0.0017	0.0014	1.83	0.38
12	2	1" centers interlaced	1/4x4	2.0	2,500	1,700[4]	1,544	0.00084	0.0011	1.27	0.26
13	1	2" Standard tube around 1 1/4 extra heavy tube		1.09 0.89	800		765	0.0017	0.00078	1.25	0.26
14	1	1/2" centers	1/4x8	2.0	2,600	1,800[4]	1,544	0.00084	0.00076	0.98	0.20
15	3	1" centers interlaced	1/4x4	3.0	3,500	2,400[4]	2,315	0.00056	0.0007	0.83	0.17
16	1	4" Standard tube around 3 extra heavy tube		3.18 3.05	2,000		2,410	0.00054	0.0005	0.64	0.13
17	1	1/2" centers	1/4x12	3.0	3,600	2,500[4]	2,315	0.00056	0.0005	0.64	0.13

Notes: 1. Extrapolated from test data.
2. Housing material, size, and color affect rating to marked degree.
3. Reactance may be as much as 5 per cent to 20 per cent higher if bus is in magnetic housing.
4. Nonmagnetic housing.

Table IV. Chance of Simultaneous or Interfering Welds

Number of Machines	Weld Time (Cycles)	Welds Per Hour Per Machine	Total Output Per Hour	Time Interval Between Simultaneous Welds: Two Welds Together	Time Interval Between Simultaneous Welds: Three Welds Together	Number of Good Welds for Every Weld in Which Three Hit Together	Total Time Divided by Weld Time of All Welders
5	3	100	500	52 hr	12,500 hr	6,250,000	144
5	3	200	1,000	6.5 hr	777 hr	777,000	72
5	3	300	1,500	1.9 hr	154 hr	231,000	48
5	10	100	500	4.2 hr	336 hr	168,000	43
5	10	200	1,000	35 min	21 hr	21,000	22
5	10	300	1,500	10 min	4.2 hr	6,200	14
3	30	100	300	2.9 hr	207 hr	62,200	24
3	30	200	600	22 min	13 hr	7,760	12
3	30	300	900	6 min	2.6 hr	2,310	8
5	30	100	500	31 min	12.4 hr	6,220	14
5	30	200	1,000	4 min	47 min*	778	7
10	3	100	1,000	5.8 hr	518 hr	518,000	72
10	3	200	2,000	43 min	32.4 hr	65,000	36
10	3	300	3,000	13 min	6.4 hr	19,200	24
10	10	100	1,000	31 min	14 hr	14,000	22
10	10	200	2,000	4 min	52 min*	1,743	11
10	10	300	3,000	1 min	10 min*	520	7
10	30	100	1,000	3 min	28 min*	467	7
20	3	100	2,000	41 min	27 hr	54,000	36
20	3	200	4,000	5 min	1.7 hr	6,840	18
20	3	300	6,000	2 min	20 min*	2,020	12
20	10	100	2,000	4 min	44 min*	1,480	11

*NOTE: On border line of unsatisfactory operating conditions if supply system is designed for ten per cent voltage drop for operation of largest machine. For these conditions supply system should probably be designed for about five per cent voltage drop.

actance of six 250,000-circ-mil interlaced standard-strand, rubber-insulated cables 1,000 feet long and arranged similar to item 8, table II, arranged as follows:

(+1) (−4) (+2)
(−6) (+3) (−5)

The copper diameter is 0.576 inch, the rubber thickness is 0.094 inch, and the braid thickness is 0.020 inch, giving a total diameter of 0.804 inch. The distance between the center lines of each conductor and all of the other conductors should be calculated and the corresponding reactances should be obtained from figure 5.

The distance between the center lines of conductors 1 and 3 is $\sqrt{0.804''+0.804''}=1.138$ inches and the corresponding reactance is 0.0368 ohm per 1,000 feet. The remaining reactances can be found in a similar manner.

$$X_1=0.0288+0.0288+0.0473-0.0448-0.0368=0.0233$$

$$X_2=0.0288+0.0473+0.0288-0.0448-0.0368=0.0233$$

$$X_3=0.0288+0.0288+0.0288-0.0368-0.0368=0.0128$$

$$X_T=\frac{2}{9}(X_1+X_2+X_3)=\frac{2}{9}(0.0233+0.0233+0.0128)=0.0132 \text{ ohm (going and return)}$$

The reactance of concentric tubular busses is easily expressible in a formula. Let the outer radius of the outer tube be r_4, the inner radius of the outer tube be r_3, the outer radius of the inner tube be r_2, and the inner radius of the inner tube be r_1. The reactance then can be expressed as:

$$X=11.49\ 4.606\left(\log_{10}\frac{r_3}{r_2}+\frac{r_1^4}{(r_2^2-r_1^2)^2}\log_{10}\frac{r_2}{r_1}+\frac{r_4^4}{(r_4^2-r_3^2)^2}\log_{10}\frac{r_4}{r_3}\right)-\frac{r_2^2+r_1^2}{2(r_2^2-r_1^2)}-\frac{r_4^2+r_3^2}{2(r_4^2-r_3^2)}\Bigg]\times 10^{-3}$$

where X is in ohms per 1,000 feet of bus (total going and return circuit)

Feeder Data for Small Installations

In cases of small installations of welders served at low voltage (240 or 480 volts) by the power company the plant wiring will generally consist of wires pulled in conduit. It is usually unnecessary to lace the going and return wires together for minimum spacing before pulling in conduit, as the natural positioning of the wires in the conduit will give close enough spacing.

The following table V gives the impedances of circuits and current-carrying capacities of relatively small wires suitable for small installations.

TYPICAL EXAMPLES

Example 1. Small Job-Welding Shop

Machines:
One 150-kva seam welder
Four 20-kva spot welders

Maximum kilovolt-ampere load swing of largest machine:
1,500 amperes at 240 volts = 360 kva

Regulation for 360 kva:	Per Cent
1. Supply system (4,800 volts)	3.0
2. 200-kva, single-phase, 4,800/240-volt, 3-per-cent, Z transformer	5.5
3. 100 feet two 4/0 wires per leg in conduit	2.3
Total	10.8

Equivalent continuous thermal loading:
0.7×150 kva = 105
0.1×4×20 kva = 8

113 kva = 470 amperes at 240 volts

Example 2. Small Job-Welding Shop

Machines.
Three 50-kva spot welders
Two 150-kva press welders
One 200-kva projection welder

Maximum kilovolt-ampere load swing of largest machine:
2,100 amperes at 240 volts = 500 kva

Regulation for 500 kva:	Per Cent
1. Supply system (4,800 volts)	4.1
2. 500-kva, single-phase, 4,800/240-volt, 3-per-cent, Z transformer	2.9
3. 150 feet one 1/4-inch by 4-inch bar per leg, 1-inch centers	3.7
Total	10.6

Table V.—Impedance and Carrying Capacity of Conductors in One Conduit

Wire Size	Conduit Size (Inches)	Resistance One Conductor Per 1,000 Feet (Ohm)	Reactance One Conductor Per 1,000 Feet (Ohm)	Current-Carrying Capacity (Amperes) Copper, 60 Deg C Ambient, 30 Deg C
2	1 1/4	0.156	0.040	107
0	1 1/2	0.098	0.041	139
2/0	2	0.078	0.038	160
3/0	2	0.062	0.036	182
4/0	2	0.049	0.038	210

Equivalent continuous thermal loading:
10 per cent×650 kva=65 kva=270 amperes at 240 volts

Example 3. Small Manufacturing Plant

Machines:
Five 250-kva press welders
Two 50-kva spot welders
Eight 30-kva spot welders

Maximum kilovolt-ampere load swing of largest machine:
825 amperes at 485 volts=400 kva

Regulation for 400 kva:	Per Cent
1. Supply system (24,000 volts)	1.1
2. 700-kva, single-phase, 24,000/485-volt, 13-per-cent, *Z* transformers	7.4
3. 150 feet one 1/4-inch by 2-inch bar per leg, 2 1/4-inch centers	2.0
Total	10.5

Equivalent continuous thermal loading:
Practically all three-cycle welding so use about five per cent of sum of connected load
0.05×1,590 kva=80 kva=165 amperes at 485 volts

Example 4. Small Manufacturing Plant

Machines:
Two 150-kva projection welders (automatic feed)
One 75-kva spot welder
One 50-kva spot welder
Eleven 25-kva portable welders

Maximum kilovolt-ampere load swing of largest machine:
850 amperes at 240 volts=205 kva

Regulation for 205 kva:	Per Cent
1. Supply system (4,800 volts)	2.7
2. 600-kva, three-phase, 4,800/240-volt, 5-per-cent, *Z* power transformer bank	3.4
3. 170 feet two 4/0 wires per leg in conduit	2.6
Total	8.7

Equivalent continuous thermal loading:
150-kva projection welder
2,000 welds per hour—3-cycle welds
Duty cycle=(2,000×3)/(60×60×60)=2.77 per cent
200 kva at 2.77 per cent duty cycle=34 kva continuous
Two machines=2×34=68 kva continuous
Remaining machines, 10 per cent×400=40 kva
Total, 108 kva

Example 5. Large Manufacturing Plant

Location *A*. Connect to Phase *AB*

Machines:
Three 550-kva butt welders
One 500-kva projection welder
One 400-kva projection welder
Three 150-kva projection welders

Maximum kilovolt-ampere load swing of largest machine:
2,700 amperes at 480 volts=1,300 kva

Regulation for 1,300 kva:	Per Cent
1. Supply system (4,800 volts)	5.6
2. Three 500-kva, single-phase, 4,800/480-volt, 3 1/2-per-cent, *Z* transformer	3.0
3. 125 feet two 1/4-inch by 4-inch bars per leg, interlaced 2 1/4-inch centers	1.7
Total	10.3

Equivalent continuous thermal loading:
550-kva butt welder
200 welds per hour—30-cycle welds
Duty cycle=(200×30)/(60×60×60)=2.77 per cent
1,300 kva at 2.77 per cent duty cycle=216 kva continuous
Three machines=3×216=648 kva continuous
Remaining machines, 10 per cent × 1,350=135 kva
Total, 783 kva=1,670 amperes at 480 volts

Location *B*. Connect to Phase *BC*

Machines:
40 hydromatic welders, 150 to 300 kva each
Total connected load=7,000 kva

Maximum kilovolt-ampere load swing of largest machine:
2,100 amperes at 480 volts=1,000 kva

Regulation for 1,000 kva:	Per Cent
1. Supply system (4,800 volts)	4.1
2. Two 500-kva, single-phase, 4,800/480-volt, 3 1/2-per-cent, *Z* transformers	3.5
3. 200 feet two 1/4-inch by 4-inch bars per leg, interlaced 2 1/4-inch centers	1.9
Total	9.5

Equivalent continuous thermal loading:
15 per cent×7,000 kva=1,050 kva=2,200 amperes at 480 volts

Location *C*. Connect to Phase *CA*

Machines:
Two 700-kva butt welders
Two 500-kva butt welders

Maximum kilovolt-ampere load swing of largest machine:
3,500 amperes at 480 volts=1,670 kva

Regulation for 1,670 kva:	Per Cent
1. Supply system (4,800 volts)	6.9
2. Three 500-kva, single-phase, 4,800/480-volt, 3 1/2-per-cent, *Z* transformers	4.0
3. 150 feet two double 1/4-inch by 3-inch bars per leg, interlaced 3-inch centers	3.1
Total	14.0

The two 700-kva machines were interlocked so that they could not be operated together and the two 500-kva machines were also interlocked.

Equivalent continuous thermal loading:
700-kva welder
100 welds per hour—2 1/2 second welds
Duty cycle=(100×2 1/2×60)/(60×60×60)=6.95 per cent
1,670 kva at 6.95 per cent duty cycle=440 kva
Two machines=2×440=880 kva
500-kva welder
100 welds per hour—2 second welds
Duty cycle=(100×2×60)/(60×60×60)=5.55 per cent
1,200 kva at 5.55 per cent duty cycle=283 kva
Two machines=2×283=566 kva
Total, 880+566=1,446 kva

Reference

1. Reactance Chart for Welder Bus Problems, **R. C. Bouse** and **J. D. Scarbrough**. *Electrical World*, volume 115, No. 10, March 8, 1941 page 106

Personnel of AIEE subcommittee on power supply for welding operations: L. W. Clark, *chairman*; E. F. Dissmeyer, M. B. Gathman, C. E. Heitman, W. F. Hess, E. A. Hester, H. S. Hubbard, S. M. Humphrey, A. H. Lewis, G. S. Mikhalapov, C. L. Pfeiffer, F. H. Roby, and F. E. Sanford.

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FUTURE MEETINGS AND CONVENTIONS

June 16–20. American Institute of Electrical Engineers, summer convention, Toronto.

June 23–27. American Society for Testing Materials, 44th annual meeting, Palmer House, Chicago.

Aug. 12–15. Regional meeting, A.I.M.E. Duluth and the Iron Ranges.

August 27–29. American Institute of Electrical Engineers, Pacific Coast convention. Yellowstone National Park.

Sept. 8–12. American Chemical Society, Atlantic City, N. J.

Sept. 17–19. Annual meeting, National Petroleum Association, Hotel Traymore, Atlantic City, N. J.

Sept. 29–Oct. 2. 8th Annual Metal Mining Convention and Exposition, The American Mining Congress, Fairmont Hotel, San Francisco.

Oct. 6–10. 30th National Safety Congress and Exposition, Stevens Hotel, Chicago. W. H. Cameron, 20 N. Wacker Drive, Chicago, managing director.

Oct. 16–18. Petroleum Division, A.I.M.E., Dallas.

Oct. 20–24. Annual Meeting, American Welding Society, Bellevue-Stratford Hotel, Philadelphia.

Nov. 3–7. American Petroleum Institute, 22nd annual meeting, San Francisco.

Welding Metallurgy

VOLUME II

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in The Welding Journal. The lectures are reproduced in attractive booklet form, copiously illustrated—357 pages—with imitation black leather covers. Volume 1 consists of the first series of 10 lectures given by the New York Section in cooperation with the Polytechnic Institute of Brooklyn last year. Volume 2 includes the series of lectures given this year. The price of the book containing both volumes is $1.50 per copy. Special prices can be arranged for quantity lots of 50 or more.

Part V—Fluxes and Slags

Flux is used in the welding of nearly every metal except lead and platinum, unless the weld is made by the resistance process in which molten weld metal, if any is formed, is not exposed to the air. Flux is the material used primarily to protect the weld melt from the air. The flux reacts with the weld melt to form the slag, which floats on the melt (see Fig. 46, Part VII of Vol. I). The following sections show the conditions that make flux essential, point out some of the requirements of fluxes and slags, describe the reactions between slag and weld metal and apply the results to oxygen cutting.

OXIDATION OF IRON

Suppose molten iron in a crucible, Fig. 37 (*a*), is exposed to the air. Oxygen molecules of the air bounce on the surface of the melt. Some molecules are attracted so strongly by the atoms of iron at the surface of the melt that the molecules are split into two atoms, and the oxygen atoms mix with the iron atoms in the surface of the melt, Fig. 37 (*b*). In other words, the oxygen dissolves in the iron. There being more oxygen atoms in the surface layers than deeper beneath the surface, oxygen atoms diffuse deeper and eventually spread throughout the melt, Fig. 37 (*c*). The process is extremely rapid. The iron atoms cannot hold more than 0.2% by weight of oxygen in solution at the melting point (oxygen in iron lowers the melting point and widens the point to a range).

When the iron contains 0.2% oxygen it is saturated. But oxygen atoms continue to force their way into the surface layers. These atoms form a new substance with the iron. No longer is the mixture of iron and oxygen atoms a single liquid. Instead, the new substance, a liquid containing 22% oxygen, is lighter than the saturated solution of oxygen in iron. The new substance rises to the surface to form a layer, Fig. 37 (*d*). Air no longer is in contact with the iron. The oxygen molecules bounce on the new layer, which is called FeO by everyone; although it may contain 22 to 28% oxygen or more and hence is not necessarily of the precise composition

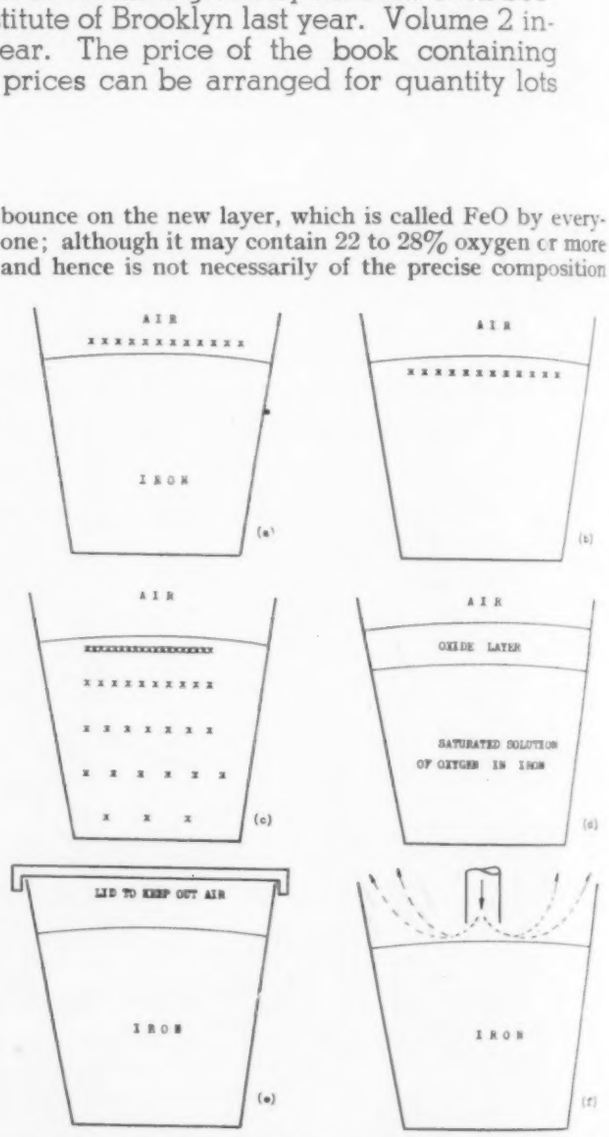

Fig. 37 (*a*) to (*d*)—Four Stages in the Oxidation of a Crucible of Molten Iron Exposed to the Air

Oxygen atoms = *x*. In *(b)* the iron at the top is nearly saturated with oxygen, in *(c)* the oxygen atoms have diffused to the bottom of the crucible, and the melt is a nearly saturated solution of oxygen in iron. In *(d)* a layer of oxide has formed on the melt. The oxide is of variable oxygen content and is called FeO for short. There is a higher oxygen concentration in the upper surface of the oxide layer than in the lower surface. Air is excluded to prevent oxidation by means of a lid in *(e)* and by means of a stream of neutral gas in *(f)*.

implied by the formula. Some of the bouncing molecules split and enter the surface layers of the FeO layer, as they did the iron surface. The oxygen atoms in the surface layers of the FeO diffuse deeper, reach the iron layer, and convert more of it to FeO. Again the process is rapid, and a crucible of molten iron exposed to the air may be converted to the iron-oxygen liquid known as FeO in a few minutes, if conditions are favorable.

Oxygen dissolved in iron is bad enough, but complete conversion to FeO, the slag from oxygen cutting, is intolerable. To prevent it we may put a lid on the crucible, Fig. 37 (*e*). No oxygen reaches the iron and there is no oxidation. We cannot put a lid over welding operations, but we can cover the weld melt with an impermeable slag equivalent to a lid. In arc welding the slags sometimes consist largely of iron oxide, silica (SiO_2) and manganese oxide (MnO). Instead of using a lid, we can drive air out of the crucible by a jet of gas that does not react with iron, helium for example, Fig. 37 (*f*). The gas shield is supplied in oxyacetylene and atomic hydrogen welding by the torch, while gas shields in arc welding are derived from combustible or volatile materials in the coating. Since these coatings frequently are carbonaceous, the gas shield consists of carbon monoxide (CO).

Three circumstances must be considered in Fig. 37. First, if the iron is near or at the boiling point, iron atoms may be rising from the surface faster than the oxygen atoms arrive. We observe then only a fume of iron and oxygen molecules rising from the top of the crucible. The surface of the iron will be clean, which may be the condition of the globules passing through the welding arc. Second, not all gases react with iron in the same way as oxygen. Hydrogen and nitrogen dissolve to some extent in molten iron but do not form compounds analogous to FeO. Other gases do not even dissolve to an appreciable extent. Third, the solubility of oxygen and other gases increases as the temperature is raised and furthermore, solution is more rapid at the higher temperatures. In arc welding, a long arc favors access of air to the melt, which however is at a lower temperature probably than with a short arc in which contamination by air is less likely. Ordinarily the access of air with a long arc outweighs in effect the high temperature associated with a short arc.

BUBBLING (OXIDATION OF STEEL)

When we substitute an iron-carbon alloy for iron in the crucible, Fig. 38 (*a*), we find in the early stages that oxygen dissolves as in iron. However, when carbon is present, only a little oxygen can dissolve in the alloy, Fig. 38 (*b*). After the melt is saturated with oxygen,

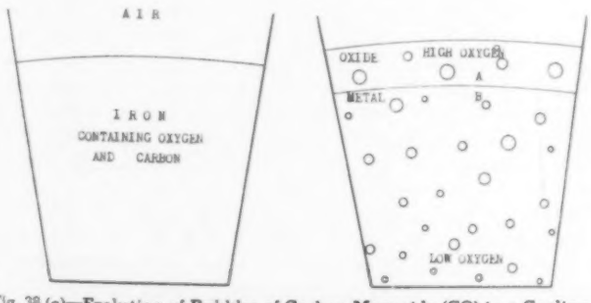

Fig. 38 (*a*)—Evolution of Bubbles of Carbon Monoxide (CO) in a Cooling Melt of Iron Containing Carbon and Oxygen

A = Region of low oxygen content in the slag (say 20% oxygen)
B = Region of high oxygen content and low carbon content in the metal (say 0.2% oxygen)
o = Bubbles of CO

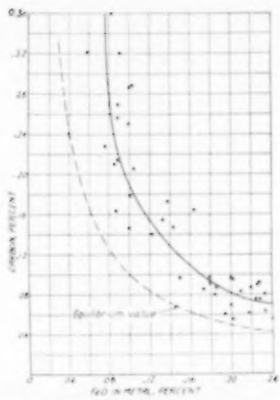

Fig. 38 (*b*)—Percentage of Oxygen in Basic Open-Hearth Steel of Different Carbon Contents

Dotted curve = Equilibrium
Full curve = Observed results showing departure from equilibrium
No data of this sort are available for weld metal

further oxygen atoms entering the melt react with carbon to form a gas: carbon monoxide. The gas under these conditions cannot remain in solution in the iron. It forms bubbles, usually at the walls. The bubbles rise to the surface. Owing to lack of time for uniformity of composition throughout the melt, the condition in Fig. 38 (*a*) easily arises. Gas bubbles through a layer of FeO that has formed on the nearly carbon-free surface before carbon has been oxidized completely from the lower parts of the melt, and in spite of the agitation of the melt by the bubbles. The bubbling gives rise to undesirable foaming of the slag during welding. The gas is derived from the weld metal, not from the slag.

The solubility of oxygen in iron and iron-carbon alloys decreases as the melt is cooled. FeO therefore separates from any cooling melt that is saturated with oxygen. If carbon is present, it reacts at once with the FeO to form CO. Thus, the bubbling continues as the melt cools. Oxygen is less soluble in solid iron than in molten iron during freezing. FeO therefore separates from the melt during freezing. As it separates, carbon at once reacts with it to form CO. Since the melt is solidifying and may be nearly solid, it is not difficult to understand that some bubbles will be trapped in the solid weld, which will contain gas holes or blow-holes. Whether the reaction continues in the solid steel after solidification and whether, if so, the pressure of the evolved gas is sufficient to cause cracks has not been determined.

Conditions will be similar if the steel contains manganese. The manganese instead of the iron will be oxidized to form manganese oxide, MnO, in the oxygen-saturated melt during cooling. Like FeO, MnO at once is reduced by carbon to form CO bubbles. If all manganese in steel is oxidized, none is left to form manganese sulphide; as a result the steel will contain iron sulphide and will be red short. Should silicon or aluminum be present in the steel, no blow-holes will appear. Silicon dioxide (silica or SiO_2) or aluminum oxide (alumina or Al_2O_3) will form when FeO separates during cooling. Neither SiO_2 or Al_2O_3 is reduced by carbon below 1600° C. Furthermore, the amount of oxygen that can dissolve in a melt containing appreciable quantities of Si or Al is negligible. On the other hand, if a melt containing Si or Al is exposed to the air, they are rapidly oxidized, the solid oxides rise to the surface, and from that point onward the melt behaves as if it contained no Si or Al, which indeed it no longer does.

Effective as are Al and Si and to a less extent Mn in freeing steel from oxygen, which has a most adverse effect on ductility and soundness, it is wasteful to add them in great excess to a welding rod or electrode in the

expectation that they will not be oxidized completely during welding. It is far better to protect the melt with a flux or a gas shield. The fluxes or coatings in arc welding are of many types, two of which are:

Composition of Flux, %	SiO_2	FeO	MnO	TiO_2	Volatile Matter
Slag type	30	30	20	20	
Gas shield type	30		20	20	30

These compositions are illustrative only; no coating in use probably has exactly these compositions, and many probably do not contain any of these constituents. Observe that these fluxes consist largely of materials that would float to the surface of a melt containing Fe, Si, Mn and titanium exposed to the air. The flux absorbs some FeO from the weld metal to form the slag on the melt.

The thicker the coating, the less opportunity will there be for diffusion of oxygen from the outer parts of the layer of slag to the melt. Also only the FeO in the slag can absorb appreciable quantities of oxygen from the air. Since FeO in the slag is largely combined as iron silicate or iron manganese silicate ($2MnO.FeO.SiO_2$), which melt at 1200–1300° C., it no longer can act as a transporter of oxygen to the melt, causing its oxidation. Hence, the slag is nearly impermeable to oxygen. With a thin coating on the electrode the slag layer is thin, absorbs a large proportion of FeO, for instance, from rust or scale on the scarves and is relatively ineffective in preventing access of oxygen to the melt unless a gas shield is maintained. The volatile matter in the coating probably burns to some extent to form CO. In either form the gas shield acts as a stream of gas from a jet to replace air by a comparatively inert atmosphere. Both flux and gas shield prevent access of nitrogen to the melt in a similar way. The action of slag in preventing access of nitrogen to the tip of the electrode is not understood. Of course, there is no relation necessarily between the gases evolved by an electrode coating or from a welding flame, and the gases in the weld metal.

THE MAJOR WELDING PROCESSES

Atomic Hydrogen Welding

To illustrate the nature of the flux and slag in some of the major welding processes, let us begin with atomic hydrogen welding. A stream of molecular hydrogen (a molecule of hydrogen consists of two hydrogen atoms) is passed across a tungsten arc. The arc heats the hydrogen to a high temperature, perhaps 5000° C. Leaving the arc, the hydrogen strikes the metal to be welded, raising its temperature and melting it. Another factor is important in the process. At high temperatures molecules of hydrogen fall apart. Each molecule of hydrogen becomes two separate hydrogen atoms. To disconnect the hydrogen atoms in a molecule requires heat, which is provided by the arc. When the hydrogen atoms cool below the temperatures at which the molecules fell apart, the atoms connect together in pairs again with the evolution of heat. The relatively cool surface of the metal to be welded provides the low temperature necessary for atoms to join to form molecules. The heat liberated by the junction raises the temperature of the metal. The flame in atomic hydrogen welding heats the metal not only by imparting its thermal energy, but also by imparting the heat of combination of hydrogen atoms.

The flame in atomic hydrogen welding is unlike an oxy-hydrogen flame in which heat is produced by the combination of hydrogen with oxygen to form water vapor. The atomic hydrogen welding flame is not truly a flame; it is a stream of heated gas. The flow of hydrogen is adjusted to prevent admixture with the surrounding air. On the outer surface of the hydrogen stream combination of hydrogen with oxygen occurs, which is essential to the process only in so far as it prevents oxygen from diffusing far into the hydrogen stream. The metal being welded is surrounded by hot hydrogen. Small amounts of iron oxide on the steel are reduced to iron by the hydrogen. No flux ordinarily is required, for there is no oxygen and consequently no oxide. The oxides of some metals, such as aluminum and chromium, are not rapidly reduced to metal by hydrogen even at high temperatures. For these metals, that is, aluminum, magnesium and stainless steel, flux is used particularly on the underside of the weld to which the stream of hydrogen cannot penetrate sufficiently.

Oxyacetylene Welding

Other torch and arc-welding processes usually require flux. In oxyacetylene welding—and the same principles apply to other oxy-fuel gas processes—the combination of oxygen with acetylene creates a stream of hot gas consisting of a complex mixture of water vapor, carbon monoxide and other products. If the acetylene content of the gas is high before combustion at the tip of the torch, iron oxide on the metal is reduced. However, the carbon content of the metal is likely to rise. Absorption of carbon lowers the melting temperature of the steel, which hastens welding, but also may lower the ductility of the weld metal.

On the other hand, if the mixture issuing from the tip before combustion is high in oxygen, the weld metal will be converted partly to oxide according to the process in Fig. 37. Carbon will be removed from the melt as bubbles of carbon monoxide (frothing), the melt being saturated with oxygen and being covered with a layer of iron oxide. It is conceivable to so proportion the mixture of gases in the torch that neither oxidation nor carburization will occur. The ideal is difficult to realize, because (1) the welder moves his flame about while he is welding a given area, and (2) owing to infiltration of air into the flame, the gases in the flame become increasingly oxidizing as they flow farther beyond the inner blue cone. It is difficult to maintain all parts of the weld puddle at the same zone in the flame.

Unlike the atomic hydrogen process, therefore, it is difficult to be certain that the gas coming in contact with the metal in torch and arc welding neither carburizes nor oxidizes the metal excessively. That is to say, it is difficult to maintain neutral conditions. For this reason flux is imperative. A common flux is borax, otherwise known as sodium borate. Many other fluxes also may be used, and may consist of a large number of ingredients.

Common borax contains a great deal of water combined in crystalline form. The water bubbles off at low temperatures during heating, the borate itself becoming fluid at about 700° C., when the steel is becoming red. The borax coats the rod and scarves as a liquid film which prevents access of air (oxygen) to the steel. Any iron oxide formed in the melt dissolves in the borax, which becomes a dilute solution of iron oxide in borax. Following basic principles (partition or distribution principle), since the percentage of iron oxide in the borax is small, the percentage of iron oxide in the weld metal likewise is small. In other words, satisfactory weld metal is secured. For a given weld the thicker the borax layer, the lower is its percentage of iron oxide. However, with a thick layer of flux it is difficult to apply heat to the metal, for the flux acts as an insulating blanket between

flame and steel. The thickness of the flux layer on the melt depends not only on the amount of flux used, but also on the type of weld, surface tension and viscosity.

Impurities, if any, in the welding gases may be absorbed by the weld puddle. Similar absorption of impurities from the flame is observed in open-hearth steel making. As the percentage of sulphur in the fuel and flame increases, the percentage of sulphur in the metal increases, again in accordance with the partition principle. In one process of torch welding flux is added through the flame by passing the fuel gas through a saturated solution of borax in alcohol. Alloying elements in the filler rod may influence fluxing. For instance, if the rod contains silicon (say, 0.75% Si), it oxidizes in the melt before iron itself. The silicon combines with any oxygen in the melt to form silicon dioxide (silica = SiO_2). The solid silica rises to the surface of the melt and dissolves in the borax. Aluminum (about 0.25%) also has been added to filler rods. The oxidation of the aluminum in the rod purposely is favored by maintaining an oxidizing flame. The heat liberated by the oxidation of the aluminum hastens welding ("activated" welding of mild steel). The use of a strongly oxidizing flame for steel is not countenanced under any other circumstances. For brass welding, on the contrary, an oxidizing flame is necessary to maintain a film of zinc oxide over the melt through which zinc cannot evaporate. With a reducing flame there is no oxide film on the melt. Zinc evaporates from the melt in the same way that gasoline evaporates from a heated pan. On contact with air the evaporated zinc burns to a powdery oxide which is useless to prevent loss of zinc by evaporation from the melt.

Carbon Arc Welding

The flux requirements for carbon arc welding are intermediate between those for gas welding and metal arc welding. The carbon arc is drawn between the carbon electrode and the metal to be welded. Like any other welding arc the carbon arc consists of ionized particles of electrode and of metal to be welded. "Ionized particles" are atoms that have lost an electron. They have short lives and exist only in the arc, to which, by their extremely rapid motion, they impart the characteristic of high temperature. For high temperature is nothing more than rapid motion of atoms, molecular or ions. Besides ions of carbon and metal, there are substances in the arc derived from the air, such as the unstable compound CN, and the oxides of carbon. The concentration of oxygen in the carbon arc is believed to be highest at the surface of the arc, lowest at the center. In this respect the arc resembles a flame in air. In principle, though not necessarily to the same degree, the identical difficulty is encountered in providing a neutral atmosphere around the weld puddle in carbon arc welding as in oxyacetylene welding. Too long an arc has a relatively oxidizing atmosphere, whereas with too short an arc the weld puddle may absorb carbon, apart from purely manipulative characteristics of short and long arcs, and apart from the effects of magnetic fields in contracting the stream of ions constituting the arc.

Flux commonly is applied to the edges of sheets to be carbon arc welded, the flux performing the same functions as in gas welding. At this point it should be clear that the heat in arc welding is generated and delivered to the metal by a gas which surrounds the weld puddle. The flux problem therefore is not essentially different in gas welding (flame welding) than in arc welding. However, besides spreading flux on the edges to be welded and on the filler rod, if any, carbon arc welders have gained control over the composition of the atmosphere surrounding the weld puddle. In gas welding the composition of the welding atmosphere is controlled by varying the mixture ratio at the torch handle. In carbon arc welding undesirable gases (oxygen) in the arc are removed by inserting a string of combustible material. The combustible material combines with the oxygen, converting it to a gas that is not soluble in steel. If the string is paper, it burns to form water vapor and mainly carbon monoxide, which are relatively inert to steel compared with oxygen itself in carbon arc welding. The string is fed into the upper part of the arc, which is the narrowest part and in which contamination by air is most serious. By removing uncombined oxygen from the carbon arc, the combustible material protects the weld puddle from oxidation and may permit welding to be performed without flux.

Bare Electrodes

Although flux frequently is used for carbon arc welding, flux is not used when the electrode is a bare steel rod instead of carbon, with the exception of the union-melt process. Arc welding with bare steel electrodes preceded the use of covered electrodes. The arc between the steel plates to be welded and the bare steel electrode consists partly of iron ions as a gas in various degrees of excitation. The rapidly moving iron ions impart their energy to the metal as well as to the air in the arc space. The air passing through the arc is converted probably to a great extent from molecular to atomic nitrogen and oxygen, in the same way that atomic hydrogen is created from molecular hydrogen by passage through a tungsten arc. Atomic (active) nitrogen has been found to assist in melting metals in about the same way as atomic hydrogen. Large drops of molten metal from the electrode periodically short circuit the arc. The weld puddle reaches a high temperature at which it dissolves comparatively large quantities of oxygen and nitrogen from the atmosphere constituting the arc. Molten steel is able to dissolve increasing amounts of oxygen and nitrogen as the temperature is raised.

The beads deposited by a bare electrode are characteristically thin. Therefore, they freeze very rapidly, particularly in the absence of an insulating blanket of slag. From the high temperature of the globules passing across the arc, the small weld puddle from a bare electrode freezes in a second or so. During slow cooling the steel would become supersaturated in oxygen and nitrogen. The latter would be evolved as gas bubbles, the former as iron oxide, which would rise to the surface of the puddle. During rapid cooling, on the contrary, the oxygen and nitrogen are retained in supersaturated solution. The iron oxide formed by the oxygen has no time to rise and remains disseminated throughout the weld metal as tiny globules. Some oxygen remains in solid solution to create undesirable aging effects and brittleness. Nitrogen, too, is retained in supersaturated solution in the metal during rapid cooling. It may appear as nitride, Fe_4N which again may destroy ductility. To show that it is the rapid cooling that accounts for the large quantities of oxygen and nitrogen in bare electrode weld metal, it is sufficient to remelt some in a neutral atmosphere. The oxygen and nitrogen are evolved during remelting, the remelted weld metal being as free from oxygen and nitrogen as remelted wrought steel.

Any metal exposed to any gas retains a maximum amount (saturation percentage) of the gas in solution, the amount depending in each instance on the pressure and temperature of the gas. If the pressure of gas A is reduced by diluting it with another gas B, the metal evolves some of gas A but absorbs some of gas B. At first sight it may seem impossible to free weld metal

from gas by dilution, because some of gas *B* would be dissolved to replace any of gas *A* that was evolved. However, some gases are nearly insoluble in steel. In fact, only oxygen, hydrogen and nitrogen are soluble to any extent. To reduce the oxygen and nitrogen content of metal deposited by bare electrodes, we are not restricted to delaying its freezing. We may dilute the arc atmosphere around the weld puddle with gases that are practically insoluble in steel. If the atmosphere is diluted by carbon monoxide, for example, so that the atmosphere consists of 90% carbon monoxide, 7% nitrogen, 3% oxygen, there will be little oxygen and nitrogen in the weld metal. In atomic hydrogen welding the hydrogen dilutes the air to a point at which practically no air is present. One of the objects of coating an electrode is to provide conditions favorable for a neutral atmosphere.

Covered Electrodes

Had borax or similar fluxes been used on the scarves with bare electrodes as with gas and carbon arc welding, the need for covered electrodes may never have arisen. It turned out that covering the electrode was the only economical means of applying flux to the long seams that were arc welded by the metal electrode process. To spread flux on the scarves and rod would have robbed the bare electrode process of its chief advantage: rapidity.

Bare electrodes have been replaced almost entirely by covered electrodes. Covered electrodes are steel rods coated with a suitable solid flux by extrusion, dipping or wrapping. The coating performs dozens of functions, of which only a few need be mentioned. When the electrode is melting, heat is concentrated on the steel rod, and spreads to the coating by conduction. Consequently, although the coating mixture generally melts at lower temperatures than the steel rod, the rod melts ahead of the coating which forms a cylindrical shell around the upper part of the arc. Since the major part of the air sucked into an arc enters through the upper part of the arc, the function of the coating as a shell is valuable. In the Lessel copper electrode the shell may be an inch long, the arc being almost entirely shielded from the air. Flux-covered carbon electrodes for carbon arc welding never have been successful because the electrode is consumed too slowly.

Electrodes in which the flux is in a central hole through the steel rod, so-called cored electrodes do not deposit metal so free from nitrogen and oxygen as covered electrodes. Yet the cored electrode weld metal contains far less of these two elements than bare electrode weld metal. The function of the flux as a liquid blanket over the weld metal therefore is important too. The flux melts from the electrode and gathers as a liquid blanket on all parts of the weld puddle except at the arc spot. The weight of the coating is generally only about 5% of the weight of the core rod, and so the flux absorbs only a small part of the heat evolved in the arc. The slag on the weld puddle in downhand welding appears to be pushed ahead on the scarves by the advancing arc and dissolves any iron oxide (scale or rust if not excessive) on them.

The slag on covered electrode weld metal serves the same general purposes as in other welding processes. Whereas the slag on bare electrode weld metal is thin, if any, and consists of iron oxide, the iron oxide in slags on covered electrode weld metal is combined as iron silicates, which have lower melting temperatures than steel and, unlike iron oxide, are insoluble in molten steel. The slag being insoluble, none is dissolved in the weld metal; that is, the weld is free from slag, unless some is trapped mechanically. Mechanically entrapped slag has several sources. The coating at the end of the electrode may chip, owing possibly to gas evolution, shock or inversion of silica. The pieces of coating may drop into, and remain in the solidifying weld. Another source of mechanically entrapped slag is slag on preceding beads through which the electrode has failed to fuse, particularly in undercuts.

Many covered electrodes rely primarily on combustible material in the coating. The products of combustion dilute the arc atmosphere to so great an extent that it contains practically no nitrogen and uncombined oxygen. A very thin slag blanket or none at all is formed by these electrodes, which are easy to manipulate in overhead welding. All organic compounds boil below about 600° C. When the arc approaches them, they become gases that dilute the arc and combine with oxygen at the outer surfaces. In this way the gases prevent ingress of uncombined oxygen to the center of the weld puddle. The combination of oxygen with hydrocarbons yields water vapor and oxides of carbon. The expansion of the gases from the coating exerts a jet action to drive air from the vicinity of the arc. Both slag-forming and combustible materials appear together in some coatings to provide protection from oxygen and nitrogen through both dilution and blanketing.

Resistance Welding

Resistance welding is characterized by absence of flux. Notwithstanding, slag is produced in flash welding, which consists of three stages: preheating, flashing and upset. During the flashing period the preheated ends of the bars are drawn apart to form an arc, which melts the surface and coats the ends of the bars with a film of molten steel. At once the ends are brought closer together. The liquid films merge. Upon the bars being drawn apart again, the liquid bridge between the ends becomes thinner and reaches the boiling point with explosive rapidity. The burst of gaseous metal blows some of the molten metal as flash into the air. Meanwhile air penetrates between the ends and oxidizes the molten metal. During upset the oxide is squeezed out. If flash welding is improperly performed, some oxygen-rich metal remains at the joint.

When sheets are spot welded, on the other hand, pressure is maintained at all times. Air cannot reach the molten metal which forms within the contact area. A circumference of solid metal surrounds the molten center of the weld. In the event of gas evolution within the spot weld, some of the molten metal may squirt out between the sheets. If the sheets initially are free from oxide, the weld likewise is free, but should there be scale on the surface, it may contaminate the weld or may react to some extent with carbon in the steel to form blowholes of carbon monoxide. The pressure of the gas may act to offset indentation or to favor squirting. Occasionally, oxidation during the spot welding of metals sensitive to oxygen is prevented by welding under water, or by circulating a neutral or reducing gas between the sheets. The solid circumference around the molten interior of a spot weld may join by pressure welding (growth of solid crystals across the interface) without the aid of liquid metal.

Forge welding consists of heating the surfaces to be joined, placing the surfaces in contact, and hammering them together to form a weld. The scarves, as the surfaces to be welded are called, generally are heated in a fire that causes oxidation. It is true that a carburizing forge fire will create a liquid layer of high-carbon, low-oxygen metal on the surface which may facilitate welding. However, the carburization usually leads to brittleness and is difficult to control. The oxidizing fire creates a

liquid film of iron oxide. Sand is used as flux and dilutes the iron oxide by forming silicates. As a result less oxygen diffuses into the steel than without the flux. When the solid surfaces are hammered together, the fluid slag is squeezed from the joint more or less completely. The adaptability of wrought iron to forge welding lay in the silicate slag (2% by weight) of low melting temperature contained in the metal. The slag acted as flux to protect the hot iron surfaces from the air (oxygen).

PROPERTIES OF FLUX

Of the numerous requirements of a welding slag apart from impermeability to gases, only a few of the more important need be considered in detail, namely: melting point, density, viscosity and surface tension. The slag must not freeze at higher temperatures than the weld metal, otherwise slag freezes on the scarves ahead of the weld metal. The weld metal, being unable to melt the slag layer, cannot perform its function of welding with underlying base metal. The slag also must be less dense than weld metal for obvious reasons. The density requirement is easy to meet in welding steel, but the density of a flux for the light metal magnesium is the most serious consideration.

Viscosity is the force required to move one of two parallel plates at unit velocity, the plates being separated by a unit thickness of the liquid under consideration. Molasses flows downhill slowly and therefore has high viscosity. Water and mercury flow downhill rapidly and have low viscosity. Fluidity is the inverse of viscosity. High viscosity signifies low fluidity. Liquids become more viscous and less fluid as the temperature is lowered. Steel a little above the melting range has about the same viscosity as water at room temperature. The viscosity of weld metals and slag is expressed in qualitative terms: creamy or watery, thick or thin.

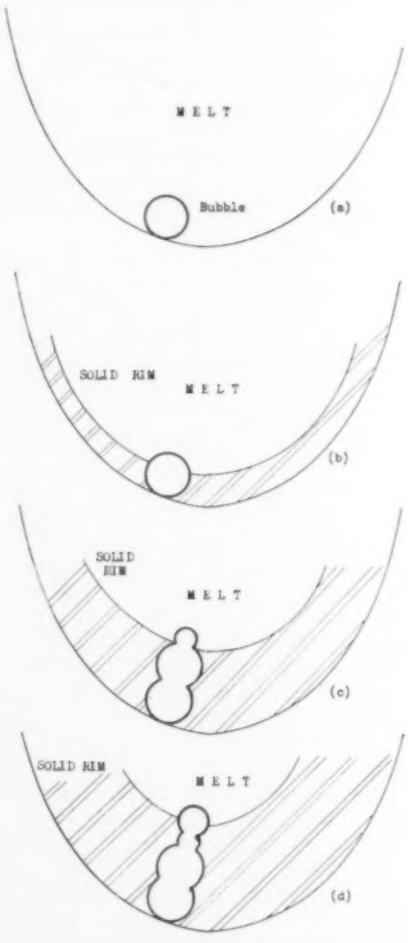

Fig. 39—Cross Section of a Weld Melt Showing Four Stages in Solidification with the Formation of a Worm Hole (See Fig. 45 of Vol. I)

If flux and slag have high viscosity at the temperatures of welding, they will be sticky and will flow slowly. Molecules cannot move rapidly in a viscous slag. Hence, they will react to only a small extent with the weld metal and on the other hand, providing they cover the melt, will be quite impermeable to gases from the atmosphere. The outer surface of the slag may dissolve oxygen, which, however, will diffuse very slowly through the slag to the weld metal. Too low viscosity is undesirable for overhead and vertical welding, for the slag will drip. Experience shows that heavy slag coatings whether of high or low viscosity cannot be manipulated in these positions. However, a slag of high viscosity, usually obtained by maintaining a cold melt (low current) is an advantage in overhead welding.

Weld metal also must have high viscosity in overhead welding. The high viscosity again is secured by preventing the temperature of the melt from rising far above the melting range. High viscosity of weld metal entails slow rise of gas bubbles or slag inclusions from the melt. Raising the temperature of weld metal lowers its viscosity, which favors rise of gas bubbles and slag inclusions. However, the high temperature favors solution of gases, which are not evolved until the temperature has fallen to that of high viscosity. Consequently, porosity is not avoided by raising the temperature of the weld melt, except in so far as high weld temperature involves slow cooling. Decrease in welding speed is an excellent preventive of porosity. Fortunately, the larger the particle, the faster it rises; but it must be remembered that whereas gas bubbles and liquid particles can coalesce, solid particles usually cannot. Any cavity or inclusion weakens a metal, because the stress in the immediate vicinity is at least twice the stress computed without consideration of the cavity.

The gas holes in weld metal generally are spherical. They have detached themselves from the crystals on which they formed and have started rising to the surface. Their rise was less rapid than the growth of the crystals. Sometimes blow-holes with several constrictions (worm holes, see Fig. 45, Vol. I) are found. Their mode of formation is illustrated in Fig. 39. At (*a*) the blow-hole has formed on a growing crystal, but has not detached itself perhaps because other crystals are above, or the melt is stagnant and no other bubbles are rising to create a liquid current. The crystals have grown partly around it at (*b*) when a new evolution of gas occurs enlarging the bubble beyond the constriction at (*c*). Several constrictions thus may occur (*d*). High viscosity of weld metal obviously favors worm holes by discouraging the rise of bubbles.

When the metal freezes there is an abrupt change in its viscosity. Tiny crystals with regular arrangements of atoms or planes, like packages on shelves, replace the liquid in which the atoms are distributed at random, like packages in a mail sack. The crystals grow in preferred directions until they can grow no further and come into contact with other growing crystals to form the polycrystalline metals which we weld. The crystals grow perpendicular to lines of equal temperature, called isotherms, in the weld. Three sections of a typical weld deposit are shown in Fig. 40, which illustrates growth of the crystals of weld metal at right angles to the isotherms of solidification (see Figs. 52 and 55 of Vol. I).

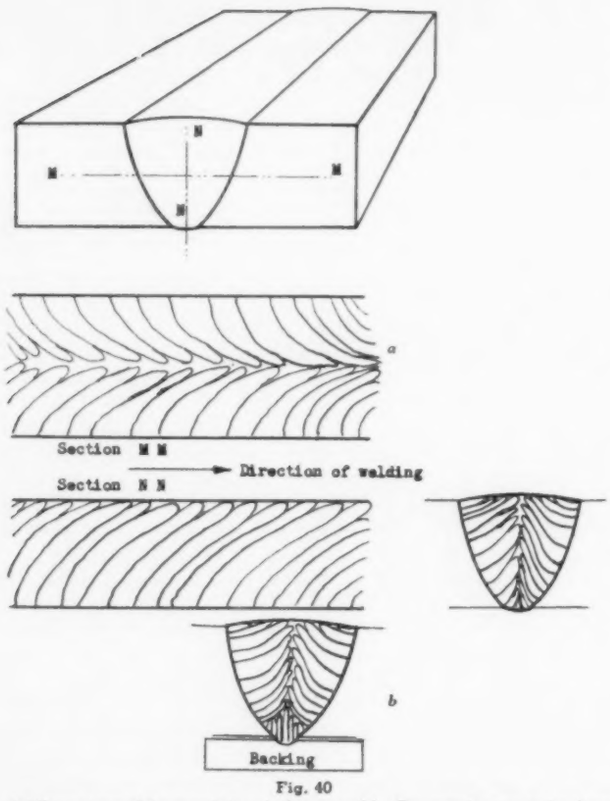

Fig. 40

(a) Three views of the crystals in a single-pass weld. The crystals grow in the direction perpendicular to lines of equal temperature during solidification
(b) A backing strip may exert a chilling action and may cause the growth of crystals vertically upward at the root of the bead

The crystals exhibit plasticity rather than viscosity. To move adjacent crystal planes over each other an initial force (yield stress) is required, in contrast with the liquids.

The slag may reach room temperature wholly or partly without crystallizing. During cooling the atoms distributed at random in the liquid slag become more and more difficult to move; the liquid becomes more and more viscous. Yet with rapid cooling no crystals may appear in it, or crystals of one or two substances only will appear. The atoms in the slag at room temperature thus are distributed at random, although not exactly random either, for the atoms of many liquids have characteristic arrangements, if not of the rigid sort manifested by crystals. Indeed, we seldom see the true structure of the weld metal as it existed in the first stages of freezing because later crystal transformations obliterate it. The columnar crystals we observe in the usual micrograph are ferrite and pearlite derived from austenite, which in turn has grown from delta iron crystals that were probably quite angular.

Surface tension, the force required to break a unit film of the material by stretching, is another property of welding slags and weld metals which, like viscosity, we can discuss only in qualitative terms for lack of quantitative measurements. At room temperature mercury has high surface tension. Globules of mercury coalesce rapidly but they do not penetrate crevices readily, nor do they wet many materials. Water, on the contrary, has low surface tension, wets many materials, penetrates the slightest crevice in a leaky pot. Mercury can be held in a handkerchief, while water passes through the holes in the mesh of which the textile is composed. Molten metals have relatively high surface tension; for example, mercury at room temperature. Molten iron has about 20 times the surface tension of water at room temperature. In general, the surface tension decreases a little as the temperature increases. Adding a small amount of alloying element of low surface tension to another metal lowers the surface tension considerably more than the corresponding rise in surface tension caused by adding an alloying element of high surface tension.

Lowering the surface tension of a metal increases the ease with which it breaks up into minute droplets. In fact, the mass of a globule passing through the welding arc is said to be directly proportional to its surface tension. Whereas large globules cause short circuits, fine globules do not. Higher melting rates accrue by decreasing the size of the globule through addition of alloying elements of low surface tension. The decrease in surface tension as temperature rises is not, however, the complete explanation of the crater beneath a welding arc.

The surface tension of weld metal is not exhibited when it is covered with oxide or slag. Oxide skins often raise the surface tension. Thus, a solid skin of alumina on any melt containing large percentages of aluminum raises the surface tension enormously and prevents wetting. Slags with low surface tension improve the wetting properties of a metal. Concave beads are deposited by hot electrodes (high temperature of weld metal signifies low surface tension) with slags of low surface tension that permit the weld metal to wet the surface of the steel and spread over it, entering any crevice at the root. The slag breaks up into fine droplets and forms an emulsion with weld metal. Slags with high content of titanium oxide (TiO_2) or fluorspar have extraordinarily low surface tension, which is said to discourage undercutting. The fine droplets of slag in the emulsion expose a large surface for reaction with the weld metal. A fine dispersion of Al_2O_3 particles in the metal lowers the surface tension (but raises the viscosity) and so favors evolution of carbon monoxide by providing nuclei for bubbles. Bubbles do not coalesce rapidly in melts having high surface tension. Hence, the bubbles, although formed earlier than in melts of high surface tension, will be smaller and will rise more slowly.

Besides viscosity and surface tension, many other requirements may be placed on the coating. It should contain no injurious impurities, such as sulphur. It may be required to contain compounds of elements such as sodium and potassium to stabilize the arc. Small quantities of these compounds suffice to stabilize the arc; if stabilization is the only function of the coating, it may be exceedingly thin. The arc may require stabilization even in the absence of arc blow, as in A.C. arc welding. In one sense a stable arc is one which is not extinguished if the electrode is moved rapidly, for example, in the flicking motions of vertical welding. The arc stabilizing compounds supply special ions to the arc and generally exert no effect on the coating or slag, which carries no current itself.

Often materials must be present in the coating to permit its satisfactory extrusion or to protect organic material from decomposition during storage. Some of these additions play no metallurgical rôle; others do. For example, waterglass, the common binder, is sodium silicate combined with water. The silicate may be the source of silica of which the welding slag later may contain large quantities. The silicate, besides acting as a binder during extrusion, is also taken advantage of as a constituent of a slag containing iron, manganese and other oxides having suitable melting range and characteristics. The slag should have a different coefficient of expansion from the weld metal to facilitate rapid removal, which also is favored by a smooth deposit.

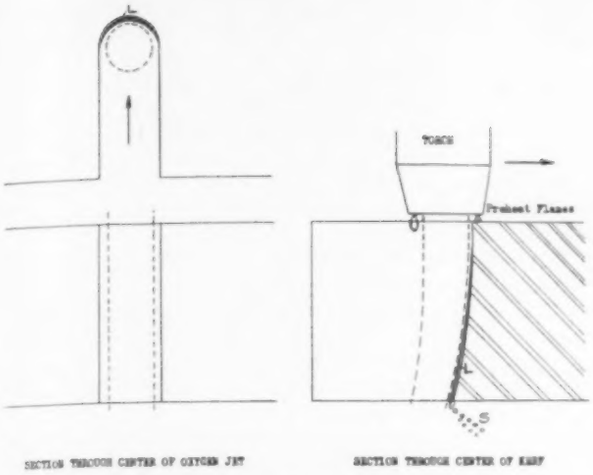

Fig. 41—Three Schematic Views of an Oxygen Cutting Torch Making a Cut in Low-Carbon Steel

The kerf is magnified greatly
Dotted line = Outline of oxygen jet
L = Film of liquid oxide on kerf
S = Spray of cutting slag blown by jet from lower edge of kerf
Arrow shows direction of motion of the oxygen cutting torch

Leaving the weld melt but returning to Fig. 37, we find therein a hint about the metallurgy of oxygen cutting. The preheating flames raise the temperature of the steel at the start of a cut. Oxygen from the cutting jet combines with the iron. The combination evolves heat which further raises the temperature. In response to the rise in temperature the combination of oxygen with iron becomes more rapid until the temperature exceeds the melting point of the oxide. The steel in the kerf then is coated with a film of oxide, the diffusion of oxygen through the film to the steel, Fig. 41, resembles the process illustrated in Fig. 37 (*d*). The liquid oxide is driven downward partly by gravity, mainly by the impulse of the jet, for overhead cutting is feasible. As the jet moves forward it thins the oxide film on the surface of the kerf. As a result, oxygen diffuses more rapidly to the surface of the steel through the thinned film. The steel in the surface layer is oxidized to liquid oxide, which thickens the film preparatory to another forward motion of the torch. Of course, the forward motion of the torch is steady and the progressive thinning and thickening of the cut may be considered as a continuous, wave-like process. Oxygen cutting also may be regarded as a process in which iron atoms dissolve in the oxide and move to the surface where they attract additional oxygen atoms from the oxygen jet to the oxide film. If oxygen cutting were performed in a room full of oxygen instead of air, the plate would burn entirely to oxide once the torch had heated one spot to the ignition temperature.

Iron is the only metal whose oxide has the requisite properties for oxygen cutting. Stainless steel, cast iron, nickel, copper and other metals may be cut with a torch by melting without significant formation of oxide. In either process, oxygen cutting or flame cutting (arc or torch), there is a heat-affected zone similar in characteristics to the heat-affected zone created by welding.

Questions

1. What characteristic of weld metal will assist it to penetrate fine crevices or permit it to bridge a poor fit-up? What characteristic is necessary to secure a concave fillet or to prevent dripping in overhead welding? Distinguish among viscosity, fluidity and surface tension.
2. Why do bubbles of carbon monoxide form in some weld melts during solidification? How can they be prevented?
3. What conditions (properties of slag and metal, motion of puddle) favor slag inclusions in weld metal? What effects may be produced during the deposition of a bead through failure to remove slag from the preceding bead?
4. What are the sources of heat in oxygen cutting? Of what does cutting slag consist?

Propeller Shaft Tubing Takes Severe Test

By H. S. Card*

IT WOULD be difficult to locate a use for steel tubing where the strength requirements are more exacting than in the case of propeller shafts which transmit the driving force of the engine to the rear axle in automobiles, buses, trucks and tractors. This will probably appear as a new thought to many who have looked upon the specifications for boiler, condenser and heat exchanger tubing as representing the most severe requirements for the tube construction.

In the first place, the propeller shaft tube has to stand a terrific torsional load at high speeds when the motor vehicle is operating normally. Added to this is the fact that those loads are often applied very suddenly under traffic conditions and just as rapidly released for sudden stopping. There are also numerous severe overloading conditions when driving in mud, ruts and other uneven road conditions. The wide-spread use of electric resistance welded steel tubing for this service is an indication of the degree to which the manufacturing of welded tubing has been perfected in recent years.

There is one quality of welded tubing which is inherent in the manufacturing process and which makes its use for this application particularly advantageous. That is concentricity. The wall of the tube is formed from cold-rolled strip steel which is uniform in thickness to a very high degree and this automatically results in the production of a tube which has a practically perfect concentric section after being welded and sized. Concentricity implies a perfectly uniform distribution of mass so that there is no undesirable "whip" when the tube is rotating at high speeds. All this is conducive to a smooth performance which is easy on the mechanism and contributes a factor of comfort for the passengers. These things are of great interest to automotive engineers but they have also to consider durability of working parts; therefore the acceptance of these advantages must depend upon the reliability of the entire structure of the tubular member.

The fact that millions of motor vehicles serve their time on the road and finally wind up in the scrap pile without ever a sign of distress in the welded propeller shaft is good enough evidence that automotive engineers have thoroughly investigated this question before adopting electric welded tubes for such an important service. An even more impressive demonstration, indicating that the safety factor is quite high, can be obtained in current practice of modern tube mills. These mills are operated

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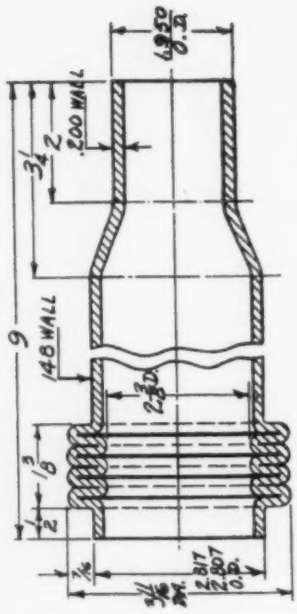


under very careful control and supervision. The control panels of the welding unit are subject to constant scrutiny and recording devices are used to keep a complete record of welding conditions as long as the mill is in operation. Even this close control is subject to continuous checking of the product itself. At regular intervals short pieces of tubing are cut off and tested to destruction. A common test for mechanical and structural tubing is to expand one end of the sample with a flaring tool until the tube wall splits and to flatten the other end of the sample in a power press or with hammer blows. It is a standard requirement that under these tests the weld area shall show no sign of distress.

Mill operations on propeller shaft tube usually have the effect of reducing instead of increasing the diameter. A typical shaft is formed from a piece of 2-in. tubing, 0.065 in. wall thickness, 58 in. long. At the ends this is swaged so as to taper down to $1^5/_8$ in. diameter, 5 in. long. This straight section is later expanded cold 0.010 in. by driving in a steel plug.

Although the normal forming operation here is not in itself a severe test of the weld area, the set-up is such that an extremely interesting test is obtained by loosening the die and allowing the tube to be pushed longitudinally against the backing die until it wrinkles. The piece illustrated has been subjected to this treatment, producing four closely spaced wrinkles concentric with the tube. The outside diameter of one of these wrinkles is $3^{11}/_{16}$ in. compared to $2^{13}/_{16}$ in. O.D. of the original tube. This amounts to 31% distortion which is 50% more severe than that obtained in the conventional crushing test for boiler tubes. Under this severe test there were no cracks found in the weld area.

A Small Portable Crucible Furnace You Can Build

By Professor C. P. Philpot*

MOST foundries are in need of a small crucible furnace for small jobs of melting which now require a large stationary furnace. With the simplicity and ease of arc-welded construction, a very useful portable furnace can be built from standard shapes and odd pieces of discarded material for less than $20—the cost varying according to available materials.

Simply follow the sketch for assembling and welding the furnace. Due to the relatively small size of the finished job, all welds were positioned for down-hand welding.

A —5 gal. Kerosene tank fabricated from 20 gage black sheet steel by welding.

B —Kerosene control valve.

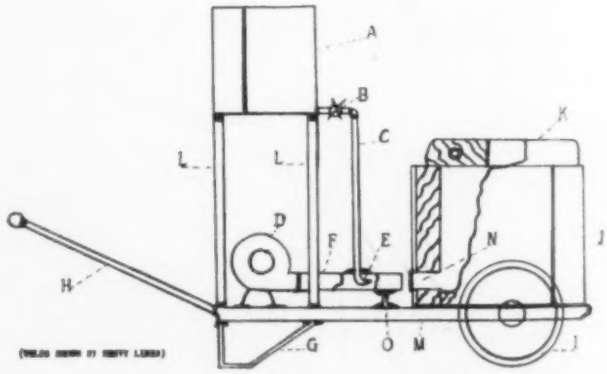
C —$^1/_8$ in. black iron pipe, end turned at *E* to right angle and welded closed—$^1/_{16}$-in. hole drilled for orifice.

D —Blower from old domestic vacuum cleaner—supports welded to frame *M*.

F —2-in. diameter steel pipe clamped to the vacuum cleaner blower and supported by welding to the frame at *O*.

G —$^3/_8$-in. x 1-in. flat steel legs welded to frame.

H —1-in. diameter steel pipe handle welded to frame.



I —14-in. diameter fabricated steel wheels. All-welded construction and mounted on a $^5/_8$-in. steel axle welded to frame.

J —Open topped steel tank, 3 ft. diameter by 2 ft. high, fabricated from $^1/_{16}$-in. sheet steel by welding and welded to frame. (This tank is later lined with 4 inches of refractory fire brick—sides and bottom.)

* Forge, Foundry & Welding Dept., Clemson College.

K—Old truck brake drum for furnace lid—$^3/_8$-in. steel rods welded in to reinforce the clay lining in lid.

L—$^1/_8$ x 1 x 1-in. angle supports for tank—welded to the frame at bottom and the tank at top.

M—$^1/_4$ x $1^1/_2$ x $1^1/_2$-in. angle iron frame, 5 ft. long, by 3 ft. wide, welded at corners and braced by welded diagonal braces.

N—2-in. diameter steel pipe welded to tank and extending through the lining into furnace.

No dimensions are given on the sketch since they may be varied to fit local conditions and the material at hand.

The operation of the furnace is very simple. Kerosene is atomized in a stream of rapidly moving air, and on entering the furnace burns with a flame hot enough to melt all of the low-temperature metals and even brass or bronze. The furnace itself is portable and may be used anywhere that a 110-volt current supply is available.

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Welding Society

ACTIVITIES — Related Events

PRESIDENT'S MESSAGE

We have emphasized the educational functions of the Society as being of the greatest importance. All sections have laid out their annual programs largely for this purpose. During the past few months some sections have developed special programs or conferences with one and two day sessions.

Among important programs are:

Tri-State Regional Conference, sponsored jointly by the Pittsburgh Section and the Engineers' Society of Western Pennsylvania, held at the Mellon Institute

The Kansas City Conference, sponsored by the Kansas City and Wichita Sections, held in the University of Kansas

The Michigan State College Conference, held under the auspices of the College with the cooperation of the Detroit Section

The Annual Symposium of the Cleveland Section

Wisconsin Engineering Conference—a joint activity of all engineering and technical societies in which the Milwaukee Section is participating

The Massachusetts Institute of Technology Conference, in cooperation with the Boston Section

These conferences have been well attended and received well merited support because of the high level of the technical contributions made.

It is especially fitting that these conferences be held at our Engineering schools. Not only is the school making a contribution to industry in organizing good technical programs but industry is making a contribution to the school. It is important that our engineers be trained with an understanding of how industry carries on its engineering development work, that they appreciate that their textbooks indicate the state of the art for yesterday—not for today—and that they be given a mental outlook that fits them to carry on for tomorrow.

CONVENTION COMMITTEE

The Convention Committee has held several meetings with the Philadelphia group to arrange the details of the Annual Meeting to be held in Philadelphia during the week of October 19th. A recent meeting was held at the Bellevue-Stratford Hotel, Society headquarters, on April 21st. There was a relatively large attendance including members of the Convention Committee, members of the National Program Committee and representatives from the Philadelphia Section. Although it is too early to announce all of the details which are receiving consideration, we can assure the membership that this will be the most interesting meeting held in the Society's history. Special plans are under way for the President's Reception, Annual Dinner, Ladies Entertainment, publicity and exhibits. A detailed tentative technical program is given elsewhere in THIS JOURNAL. The Society is greatly indebted to the Philadelphia Section and its numerous committees that are in charge of the local arrangements for the one hundred and one details that are necessary to insure the success of these meetings.

1941 (FORTY-FOURTH) A. S. T. M. ANNUAL MEETING

Sixth Exhibit of Testing Apparatus and Related Equipment

Some 17 separate technical sessions are being scheduled for the Forty-Fourth Annual Meeting of the American Society for Testing Materials to be held at The Palmer House, Chicago, during the week beginning June 23rd and extending through Friday, June 27th. This number of sessions is necessary for the presentation of the 100 technical papers and reports and to provide time for discussion.

The Sixth Exhibit of Testing Apparatus and Related Equipment will be in progress; the society sponsors these exhibits, every two years, at its annual meetings. There is also being sponsored the Fourth A. S. T. M. Photographic Exhibit on the general theme "Materials, Testing and Research."

Separate sessions of the meeting will be devoted to such topics as iron, ferro-alloys; water, which includes a Symposium on Problems and Practice in Determining Steam Purity by Conductivity Methods; non-ferrous metals (two sessions); cementitious and building materials; steel, effect of temperature; fatigue of metals, corrosion; plastics; and concrete and concrete aggregates. Also being developed is a joint session with the Western Society of Engineers dealing with three topics of specific local interest, namely, water supply, sewage disposal and sanitary conditions; and may involve some discussion of materials and problems in connection with the Chicago subway.

Throughout the week of the meeting some 200 technical committees of the society are expected to meet. All day Monday will be devoted to committee meetings. The first formal A. S. T. M. session, which is scheduled for Tuesday morning, will be featured by the address of the president, Dr. W. M. Barr, Chief Chemical and Metallurgical Engineer, Union Pacific Railroad Co., who will speak on a subject of vital concern, namely, "Speed, Specifications and Safety."

THE GOVERNMENT NEEDS AERONAUTICAL AND MECHANICAL ENGINEERS

The production, development and testing of aircraft and airplane engines is becoming of increasing importance in the National Defense program. Four Government agencies are now seeking qualified engineers who can do the critical investigative and research work connected with the development of faster, safer and more powerful airplanes. Aeronautical training is especially in demand, although much of the work now being done also requires the services of qualified civil, mechanical and electrical engineers.

The U. S. Civil Service Commission has announced open continuous examinations in all fields of Engineering. Application forms (Form 8) may be obtained at any first- or second-class post-office. The application, when properly filed, is rated immediately, and applicants rated eligible may be certified at once to an appointing officer, may be tendered an offer of employment by wire, and may be at work within a week of the time of filing applications.

The Air Corps now employs approximately 400 professional engineers at Wright Field, Dayton, Ohio, where most of the aircraft testing and developmental work of the War Department is concentrated. Many of these engineers in aeronautical and mechanical fields are engaged in checking the latest technical developments in aeronautical research and adapting and applying them to improved military aircraft. The Air Corps is particularly anxious to interest recent engineering graduates and senior students in the many opportunities afforded at Wright Field through the testing and checking of the latest advancements in airplane engine design.

The Navy Department now employs over 165 aeronautical engineers. The Bureau of Aeronautics is charged with responsibility for all that relates to the design, construction, fitting-out, testing, repair and alteration of naval aircraft and aircraft instruments, equipment and accessories.

The National Advisory Committee for Aeronautics conducts fundamental re-

INDEX TO ADVERTISERS

Air Reduction Sales Co. . . . Outside back cover
American Brass Company 391
American Chain & Cable Company, Inc. . 393
Anti-Borax Compound Company 392
Arcos Corp. . . . . Inside front cover
Bastian-Blessing Co. 390
Chicago Bridge & Iron Co. 401
Federal Machine & Welder Co. 403
Foote Mineral Co. 392
General Electric Co. 351
General Electric Company . . . . . 394 & 395
Handy & Harman Company 383
Hobart Bros. Co. 349
International Nickel Co. Inc. 405
Jewel Manufacturing Company 392
The Linde Air Products Company 352
Lincoln Electric Co. . . . . Inside back cover
P. R. Mallory & Co., Inc. 390
Metal & Thermit Corporation 387
National Carbide Corporation 388
National Time & Signal Corp. 386
Page Steel & Wire Division 393
Resistance Welder Mfrs. Association 397
Square D Company 385
Stulz-Sickels Company 385
Union Carbide and Carbon Corp. 352
U. S. Steel Corp. Subsidiaries 399
Victor Equipment Co. 389
Westinghouse Electric & Mfg. Co. 407

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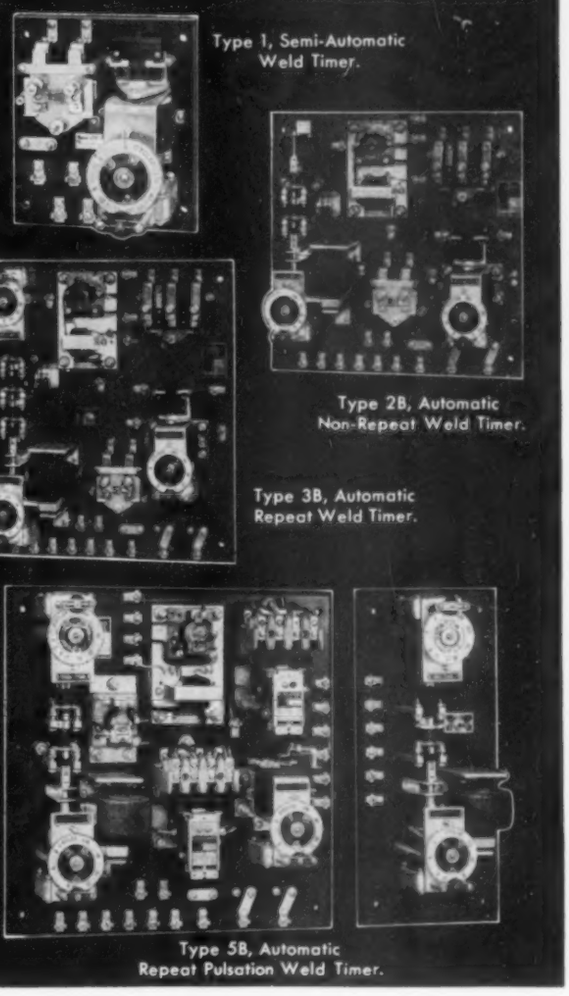

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search on the problems of flight. The Committee's major research laboratory is located at Langley Field, Virginia, while a second laboratory is partially completed at Moffett Field, California. Current projects involve investigations requiring research in aerodynamics, hydrodynamics, aircraft structures and aircraft engines; the results of research are available to governmental agencies and to those units of the aircraft industry that are most concerned. The engineer personnel has increased rapidly in the last six months, and when the new Aircraft Engine Research Laboratory at Cleveland is completed, a still greater number of qualified engineers, particularly aeronautical and mechanical, will be needed. The present personnel includes a total of 340 engineers, of which approximately fifty per cent are aeronautical and twenty-five per cent are mechanical.

The Civil Aeronautics Authority, which is chiefly concerned with the inspection and development of non-military air transport and airways, also concentrates on the testing and approval of developments in safety devices, instruments and improved designs for all types of aircraft. Research is conducted at the Bureau of Standards in Washington, D. C., and at the experimental laboratory at Indianapolis; studies are made relative to the extinguishing and prevention of aircraft fires, and an improved system for "blind" landing. At present the Authority is employing over 300 engineers, of which over twenty per cent are aeronautical.

Airplane engine development has not yet reached the stage where little remains to be done. The race to improve aircraft design is now on an international scale and the importance of succeeding in the competition to develop the perfect plane cannot be overestimated. New discoveries are being made almost daily, and events in Europe are furnishing the most exacting trial conditions for the application of new theories to aircraft. Any new discovery may revolutionize some phase of production, if properly applied by qualified engineers who understand the present problems involved in engine and aircraft design, carburetion, cooling, accessories, instruments, fuels, lubricants, etc.

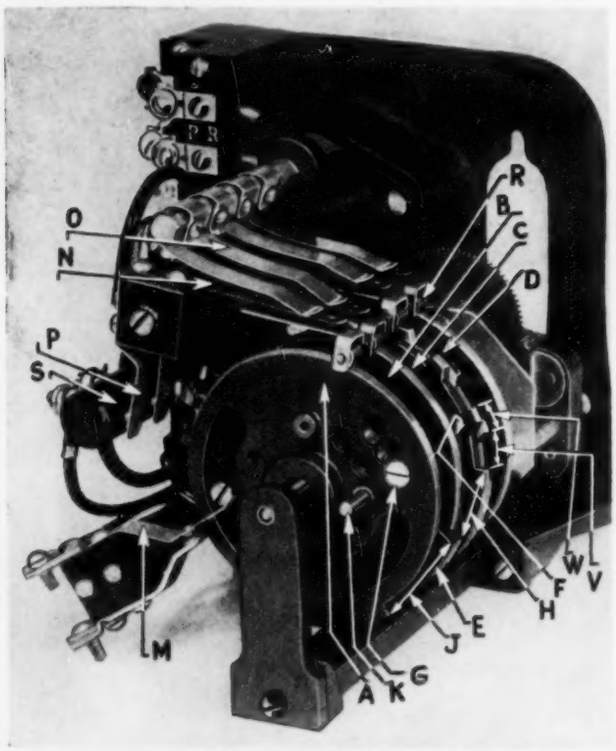
Each of the four agencies mentioned maintains research laboratories at which the major concern is the development of new testing methods to check the efficiency and practicability of current and proposed designs in aircraft and airplane engines. New fuels are being studied in relation to higher speeds, higher altitudes and longer flights. New types of engines require new lubricants, new superchargers, better carburetion, better bearings. Designs are constantly being improved to allow speedier, more thorough overhauling and easier replacement and repair of worn or damaged parts.

Improvement in the design of aircraft is going ahead rapidly. The engineer is needed to check and test each new feature of design to offset factors of weight and strength against speed and guns and armor plate. Studies are being made of propeller design, engine cowlings and airfoil design, to combine greatest speed with greatest stability and efficiency. Improved theoretical design must be applied in a usable manner to planes for service under the uncompromising conditions of modern warfare and modern transportation requirements. It is the responsibility of the United States Civil Service Commission to interest qualified engineers in the job to be done, and to furnish the Government agencies with the required personnel to carry on the program.

AIRCO REPRESENTATIVES

E. H. Anchors, formerly Manager of the Oklahoma City District of Air Reduction Sales Company, has been appointed Manager of the Birmingham District. Mr. Anchors began his career 16 years ago with the Commercial Acetylene Supply Company. He was Southern Manager of this company when it was acquired by Air Reduction. Since that time he has served as Manager at the Atlanta and Oklahoma City District Offices.

M. G. Wicker, formerly connected with the Baltimore office of Air Reduction Sales Company, has been appointed Manager of the Oklahoma City district. Mr. Wicker's eleven years with Airco have given him wide experience in the oxyacetylene welding and cutting industry. Prior to this new appointment, Mr. Wicker served in the Birmingham, Atlanta and Baltimore offices of Air Reduction.



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Through an examination announced some time ago, the Civil Service Commission has been seeking experienced men for procurement inspector positions in the Air Corps of the War Department. The Commission has not been able to obtain enough men for these positions. On the contrary, the needs have been extended to other fields than those in the original announcement. Five new fields in which persons may qualify have been added, and the options now are: Aircraft, engines, instruments, parachutes, aircraft propellers, tools and gages, radio, aircraft miscellaneous materials, textiles, fur-lined clothing and optical.

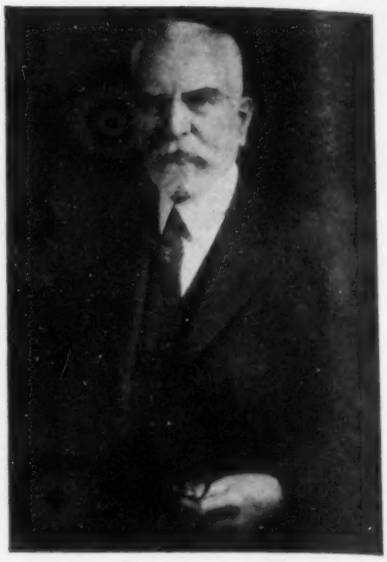
In general, mechanical experience, which may include apprenticeship, is required in the field applied for. For only four options (aircraft, parachutes, propellers, and aircraft materials) need this experience be specifically on aircraft materials. College courses in engineering may be substituted for part of the experience. Applicants will not have to take a written test, but will be rated on their experience and education. For details concerning the amended requirements applicants should consult Announcement No. 6-249 Revised of April 22, 1941.

Original appointments will be made at salaries ranging from $1620 to $2600 a year. Opportunities for advancement are excellent. Applications may be filed until further notice with the Secretary of the Board of U. S. Civil Service Examiners at Wright Field, Dayton, Ohio. Qualified persons are urged to apply for details to the Secretary at Wright Field; to any first- or second-class post office; to the U. S. Civil Service Commission, Washington, D. C.; or to any of the Commission's District offices.

OBITUARY

Dr. Otis Ellis Hovey, distinguished civil engineer and bridge designer, who was one of the world's foremost authorities on movable bridges and the director of The Engineering Foundation, died in Doctor's Hospital, New York City, after an illness of two months. His age was 77. Dr. Hovey had been treasurer of the American Society of Civil Engineers since 1921 and an honorary member of the society since 1937. His home was at 425 Riverside Drive. He had a consulting engineering office at 11 West Forty-second Street and an office at the Engineering Foundation, 29 West Thirty-ninth Street, New York.

Dr. Hovey was author of a two-volume work, "Movable Bridges," published in 1926–27. It is a standard reference on the various types of movable bridges.



Dr. Otis E. Hovey

Born April 9, 1864, in East Hardwick, Vt., Dr. Hovey was the son of the late Jabez Wadsworth Hovey and the late Mrs. Catherine Montgomery Hovey. He was graduated from Dartmouth College in 1885 with a B.S. degree and received a C.E. degree from the Thayer School of Civil Engineering, Dartmouth College, in 1889. He served thirty-four

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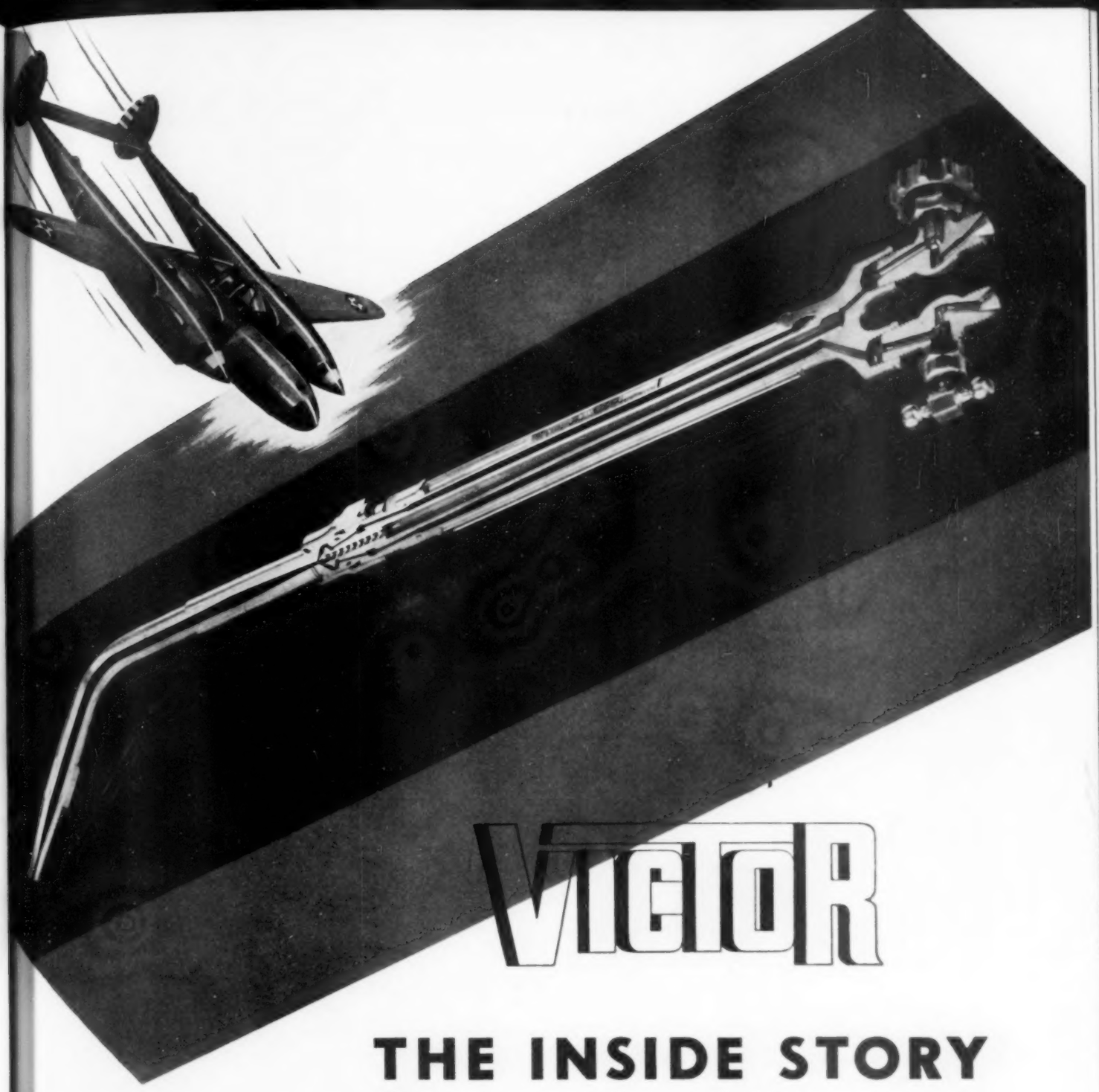

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years until his death as a member of the board of overseers of the school.

Dr. Hovey received a D.Eng. degree from Dartmouth in 1927 and a D.Sc. degree from Clarkson College in 1933.

In 1889–90 he served as an instructor in engineering at Washington University, St. Louis, before becoming an engineer of design with the late George S. Morison, consulting bridge engineer of Chicago. Under Mr. Morison he was instrumental in the designing of a viaduct for a bridge over the Mississippi River at Memphis and designed the superstructures of the Bellafontaine Bridge over the Missouri River, and of a bridge at Leavenworth, Kan.

Dr. Hovey was with Mr. Morison in 1890–96. In the latter year he became plant engineer of the Union Bridge Company at Athens, Pa., which was then engaged in constructing the steel work for the Chicago elevated railway. For the Union concern he designed a bascule bridge over the Chicago River.

In 1898 he was sent by the Union company to London, where he was a consulting engineer on projects for the erection of South African bridges.

Served in Constantinople

The American Bridge Company bought the Union plant in 1900 and Dr. Hovey became an engineer of design for the American at Pencoyd, Pa. In 1904 he went to Constantinople, Turkey, for the company, and there surveyed trade conditions.

In 1904 he also was transferred to New York by the American. He became its assistant chief engineer in 1907 and consulting engineer for the company in 1931. He left the company in 1934. While with it he was in charge of the building of emergency dams at the Panama Canal. Later he was in charge for the company of its extensive repair work on the Williamsburg Bridge in New York City.

About ten years ago he was in charge of the building by the company of the great Port of New York Authority Bayonne Bridge, connecting Bayonne, N. J., and Port Richmond, S. I., over Kill van Kull.

Dr. Hovey entered private practice in 1934 as a consulting civil engineer. For the last four years he also had been Director of the Engineering Foundation.

He was the author of "Steel Dams," published in 1935. He served on many engineering committees, wrote numerous technical papers and lectured on engineering subjects at Yale and Princeton Universities and Dartmouth College.

He leaves a widow, Mrs. Martha Owen Hovey; a son, Otis W. Hovey of Pittsburgh, Pa.; a daughter, Mrs. Ellen Catherine Davis of Hartford, Vt.; a sister, Miss Mary E. Hovey of East Hardwick, Vt., and two grandchildren.

Dr. Hovey was active in the affairs of the AMERICAN WELDING SOCIETY. For a number of years he served on the Structural Steel Welding Research Committee; was a member of the A. W. S. Bridge Committee and of the By-Laws Committee.

REPAIR OF CENTRIFUGAL PUMP BODIES

At Fort Peck, Montana, pump bodies for the project's dredging operations had to be replaced every twenty-one days. Then electric arc welding was applied to remedy this costly operation. Now the pump bodies repaired by welding bring about a savings of $3037 over the previous method of replacement.

The pump bodies welded are for centrifugal pumps driven by a 2500-horsepower motor. The body, weighing 24 tons, is mounted on the dredge in pairs. The bodies are lifted off the dredge on to

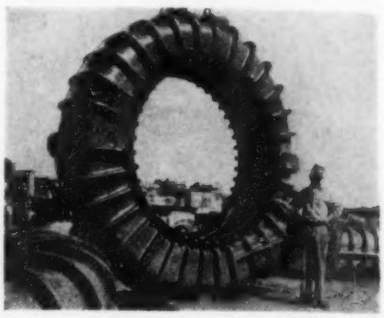


Photo courtesy Hobart Brothers Company

a barge—then towed to a yard where several welding machines are set up. Here the pump bodies are built up to the required thickness by arc welding mild steel and cast iron. Very little dressing is required except on the impellers.

For SAFETY SPEED ECONOMY

MANIFOLDS
REGULATORS
VALVES and
FITTINGS
to control high pressure gases

The BASTIAN-BLESSING Co.
282 E. ONTARIO ST. CHICAGO

Pioneers and Manufacturers of Precision Equipment for Using and Controlling High Pressure Gases

The Purchasing Agent Says

"Thanks to Mallory standardization . . . it's as easy to buy welding tips as it is pencils."

An easier job for the purchasing agent may be in itself a minor detail to the welding engineer . . . but not when it means the elimination of costly "down time" while waiting for special orders to be completed.

Yet this is just one phase of the advantages afforded through Mallory's program of standardization of welding electrodes. Mallory Welding Electrodes are actually better because of standardization. Nothing so clearly identifies the requirements of cooling, hardness, thermal and electrical conductivity as limitless field experience.

This, plus years of the closest cooperation with leading manufacturers of welding machines assures you the finest welding tips at the lowest possible costs.

MALLORY

Resistance Welding Data Book

Your engineering staff will welcome this comprehensive treatise on welding practices, alloys and specifications. Be sure to write for a copy.

P. R. MALLORY & CO., Inc., Indianapolis, Indiana • Cable Address — PELMALLO

P.R. MALLORY & CO. Inc.
MALLORY
RESISTANCE WELDING ELECTRODES

A "Wheels of Progress" Keeps Moving

THANKS TO TOBIN BRONZE!

This 2½ ton gear, although broken in several places, was back on the job only six days after it failed

This gear looked something like Humpty-Dumpty... it was so severely broken that it looked almost impossible to repair. But, here, as in many other emergencies, Tobin Bronze repair welding performed the "impossible," in the shortest possible time.

Not only does Tobin Bronze make strong, sound welds in cast and malleable iron and steel, but because of Tobin Bronze's low melting point, its use effects large savings in preheating time and fuel consumption. There is a minimum of delay in returning a Tobin Bronze welded part to service.

Tobin Bronze rods are stocked by leading jobbers throughout the country. When ordering, make sure you get genuine Tobin Bronze. Each rod is trademarked for permanent identification.

•

The Hebeler Welding Co., Buffalo, N. Y., repair-welded this 2½ ton gear in 64 man hours with 250 lbs. of Tobin Bronze. 40123

ANACONDA
from mine to consumer

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • *Subsidiary of Anaconda Copper Mining Company*

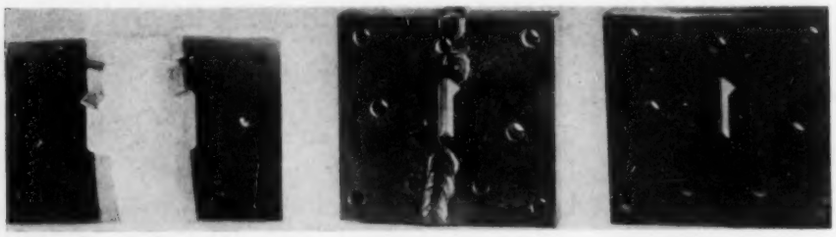
These centrifugal pumps were the only method used to put the dirt in the fill on the job. With 28-in. suction and outlets, each dredge pumped an average of 45,000 cubic yards per day. All of the earth was dredged from the Missouri River which is located about five miles from the project.

Eight hours are required to change pumps. Repairing these pumps keeps several hundred men busy twenty-four hours a day all during the dredging season.

ATOMIC HYDROGEN DIE REPAIR

More than $6000 a year and valuable time are being saved at the Bridgeport Plant of the Underwood-Elliott-Fisher Company through the use of atomic-hydrogen welding. A General Electric unit has been in use for some time in the tool room of this office appliance plant to repair broken dies and tools—parts which otherwise would have to be discarded at a loss of both money and the time required to get new parts.

Making the Repair



Typical Die Repaired with G-E Atomic-Hydrogen Welder. Broken Die at Left, Same Die (in Center), After Being Built Up by Welding Process; Die Finished and Ready for Use (at Right)

Shown in one of the photographs is a typical die repaired at this plant, showing the broken die which normally would have to be discarded; the same die after it had been built up through the welding process; and the die finished and ready for use.

METAL SPRAYING

To describe the ever-growing field of application in industry where the Metco Metallizing Process can be advantageously used for rehabilitating worn shafts and other rotating machinery, as well as protecting metal surfaces against corrosion and other chemical attack, Metallizing Engineering Company, Inc., 21-07 41st Ave., Long Island City, N. Y., has just issued a new 16-page informative bulletin No. 42 entitled "Metco Metallizing Equipment and the Metallizing Process." In addition to useful facts on how to save time, money and labor both in production and maintenance work through Metco metallizing, this bulletin also describes in detail the new Metco "Controlled Power" Metal Spraying Gun Type 2E, as well as the standard Type E Gun. Also included are descriptions of the complete line of Metco metallizing accessories.

Plan to Attend
Annual Meeting Oct. 19th–24th
Philadelphia, Pa.

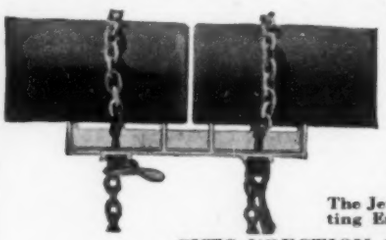
WELDING FLUXES

Calcium, Barium and Strontium Carbonate
Calcium Fluoride—Calcium Silicate
Magnesium Oxide—Powdered Glass
Lithium Fluoride and Chloride

Send for our new catalog, Foote Welding Materials, an up-to-date, factual list of complete analyses and information on over forty products. Your request will receive prompt attention.

FOOTE MINERAL COMPANY
1612 Summer St., Philadelphia, Pa.

PIPE WELDING TOOLS THAT MAKE WELDING PAY



Pipe Clamps
Flange Clamps
Elbow Clamps
Angle Clamps
Pipe Markers

TWO SIZES
½ to 8 in. 8 to 16 in.
Light—Adjustable—Fast

The Jewel System of Pipe and Fitting Erection Ready for the Weld

CUTS ERECTION COSTS
Keeps the Welder Welding Instead of Waiting

JEWEL MANUFACTURING COMPANY
1841 University Ave., St. Paul, Minn.

Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them
The Trade-Name is "ANTI-BORAX"

Ask for Them ***Unequalled for Quality***

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; "Anti-Borax" Tinning Compound No. 11.

Send for Free Samples

ANTI-BORAX COMPOUND COMPANY
Fort Wayne, Indiana

There's the STAINLESS STEEL WELDING ELECTRODE YOU WANT"

• It's listed on page 6 of this booklet on Stainless Steel Welding and Electrodes that has been prepared by PAGE.

•

You probably know as well as we do that you must look for and insist on getting two distinctly different *kinds* of quality in your Stainless Steel Electrodes.

It is imperative for good Stainless Steel Welding that the deposit *in the weld* be equal to the Stainless Steel you are welding.

It is just as important that the electrode be of the shield-arc type, to protect the metal in the weld; equally usable in horizontal, vertical and overhead positions; permit high speed welding with minimum spatter and slag loss and smooth beads.

To get all those qualities for you, PAGE worked in the field and laboratory with the world's largest producers of Stainless Steel —until they said every PAGE Stainless Electrode was *right*.

Start right, then, with your Stainless welding. Depend on PAGE. Tell your local PAGE Distributor the Stainless Steel you want to weld and accept his recommendation.

Be sure to ask your local PAGE Distributor for a copy of this valuable, well illustrated booklet on the welding of Stainless Steels. It covers the entire subject.

PAGE WELDING ELECTRODES

PAGE STEEL AND WIRE DIVISION • MONESSEN, PENNSYLVANIA

AMERICAN CHAIN & CABLE COMPANY, Inc.

"I buy *PRODUCTION*... when I buy electrodes

—and G.E.'s new production-labeled electrodes help me buy *production*. They help me to *know* the pounds of electrodes required and to estimate costs more closely than ever before."

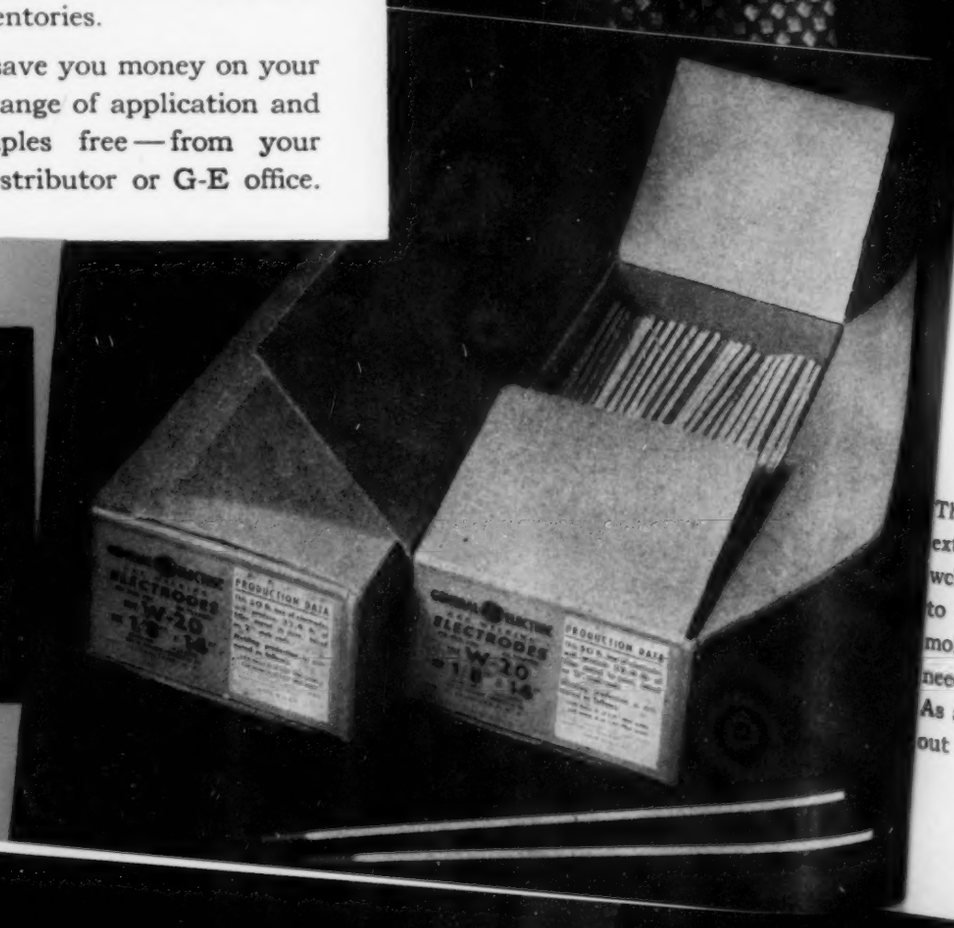
Each 50-lb box of G-E mild-steel electrodes now bears a label that gives you the estimated:

—LINEAR FOOTAGE OF WELDED JOINT OBTAINABLE

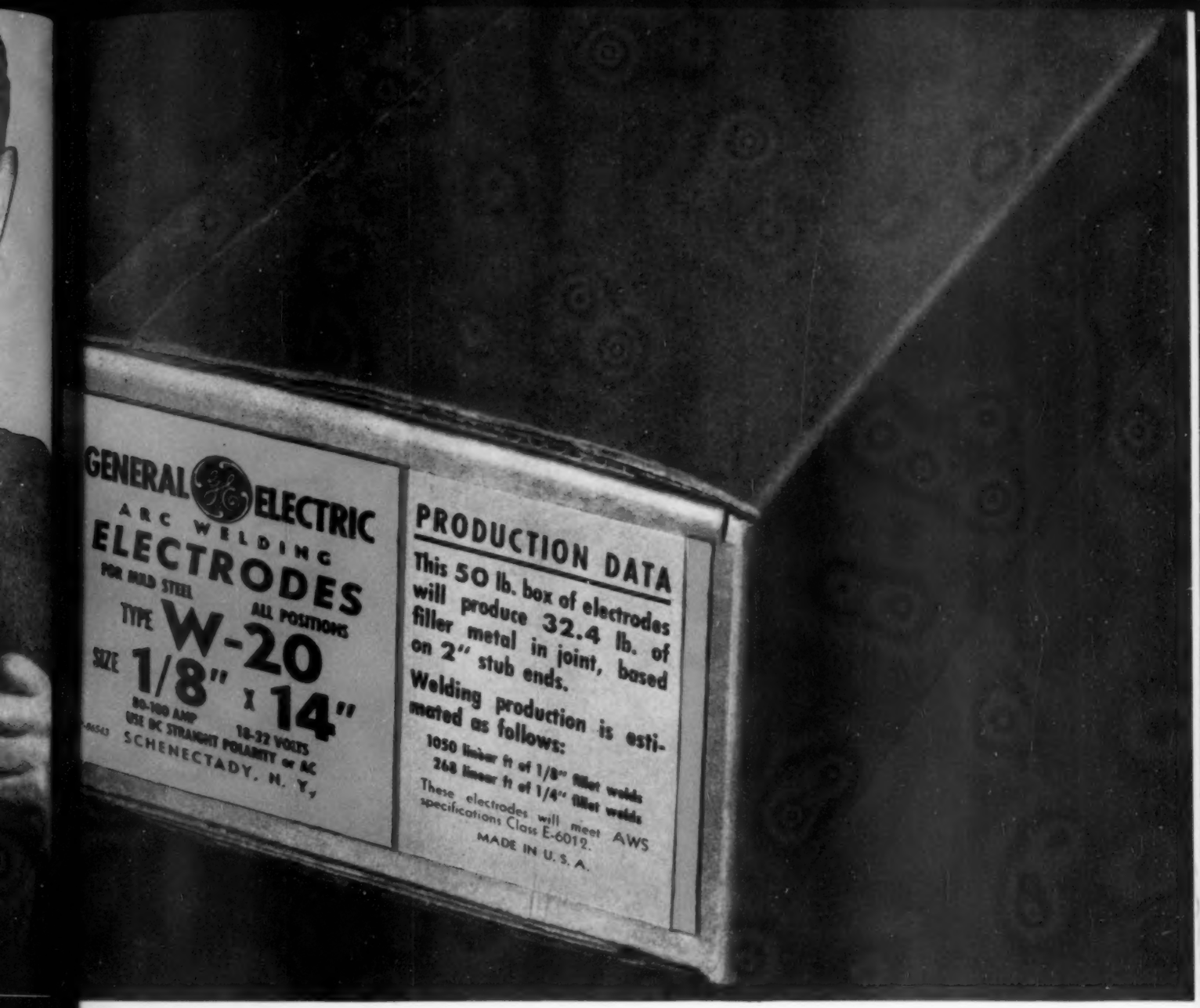
—WEIGHT OF DEPOSITED METAL OBTAINABLE

With maximum profits depending on such close margins as present-day operations allow, this new engineering service enables supervisors and foremen to co-operate more effectively with their purchasing department in avoiding shortages and top-heavy inventories.

G-E electrodes further save you money on your welding by their wide range of application and easy "usability." Samples free — from your nearest G-E welding distributor or G-E office.



Production data is available on heavily-coated, mild-steel electrodes, "all-position" types, W-20, -22, -25, -30 (1/8- to 1/4-in. dia.) and "flat-position" types, W-23 and W-24 (1/4-in. to 3/8-in. dia.). Data on other sizes on request.


GENERAL ELECTRIC
ARC WELDING
ELECTRODES
FOR MILD STEEL
ALL POSITIONS
TYPE W-20
SIZE 1/8" X 14"
80-100 AMP
18-22 VOLTS
USE DC STRAIGHT POLARITY or AC
SCHENECTADY, N. Y.
PRODUCTION DATA
This 50 lb. box of electrodes will produce 32.4 lb. of filler metal in joint, based on 2" stub ends.
Welding production is estimated as follows:
1050 linear ft of 1/8" fillet welds
268 linear ft of 1/4" fillet welds
These electrodes will meet AWS specifications Class E-6012.
MADE IN U. S. A.

Don't Forget....

It's not the pounds you buy in the box that make welding profits-- it's the footage you get in the joint that counts!

(whether you buy 'em by the box or by the car-load)

That's why G-E "production-labeled" electrodes deliver extra value all along the line—from supervisors to skilled welding operators. These rods "take the heat" right down to the holder end. At the same time, practically all the molten weld-metal is deposited in the joint where it is needed, not spattered over surfaces adjacent to the joint. As a result, welding costs are reduced and operators turn out better work—faster and easier.

A complete demonstration of these profit-building electrodes—on *your* work—is available from any G-E arc welding distributor. His stocks are fresh and offer you a dependable source of supply.

There's no obligation in sampling these G-E rods or in having a free demonstration. Why not phone or write today? Or, if you prefer, write to General Electric Co., Schenectady, New York.

GENERAL ELECTRIC

673-17-8748

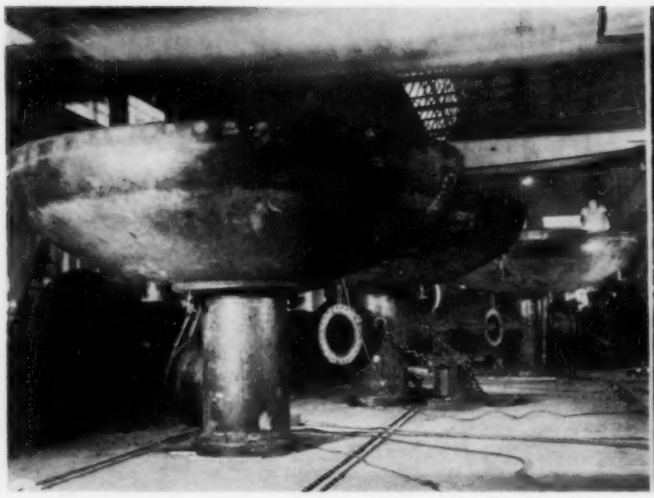


Fig. 1

Fig. 2

SOME INTERESTING PRESSURE VESSEL PHOTOGRAPHS

We are indebted to the A. O. Smith Corporation for the cover picture. This shows welding on steel sections of a stainless-lined oil fractioning tower. Inside diameters of the sections range from 5 ft. 6 in. to 16 ft. 6 in. with an over-all length of 125 ft. 1 3/4 in. The complicated design of this tower, which weighs 265,000 lb., calls for 84 manways.

Figure 1 shows welding head-assemblies for large, high-pressured oil cracking stills by the same company.

Figure 2 is a view showing welding on huge separating tower for the oil industry. The tower has a 12 ft. 0 in. inside diameter, 3 1/2 in. to 3 3/4 in.-wall, 59 ft. 6 7/16 in. over-all length and weighs 393,800 lb.

Figure 3 shows welder at work on manway of atmospheric tower. The tower has 11 ft. and 12 ft. 0 in. inside diameters, 5/8-in. wall and 100 ft. 8 5/8 in. over-all length. Designed for maximum working pressure of 30 psi, and tested to pressure of 90 psi.

Fig. 3

Photo courtesy Hobart Brothers Company

DEVELOPING YOUR TRACTOR REPAIR BUSINESS

Many tractor owners are not aware of the dependable practice of rebuilding worn tractor lugs by arc welding. Pictured above is an enterprising job shop operator who took his portable gasoline engine driven arc welder to the job and rebuilt the lugs by welding on 3/4 in. by 14-in. bars of steel. In addition to saving the contractor about $100 less than the usual replacement cost, the job shop made a nice profit. The customer was also pleased by the fact that the tractor was out of service only about one-fourth the usual length of time.

PORTABLE MACHINE-CUTTING

A revision of the booklet, "Opportunities for Profits with Portable Machine Cutting," has just been announced by The Linde Air Products Company, a Unit of Union Carbide and Carbon Corporation. This booklet describes the many advantages of oxyacetylene cutting with portable machines, the diversity of operations which can be performed and a variety of applications. Several new profitable "hints and kinks" on the use of these machines have been added.

The general operations possible—straight-line cutting, bevel cutting, shape cutting, circle cutting and heavy cutting—are illustrated in this booklet, and a number of views of cut edges are given to illustrate the results of correct and incorrect cutting techniques. In addition, some typical applications in the aircraft and automotive industries, iron and locomotive works, machine shops, job welding shops, shipyards and steel mills are listed. The section on suggestions for extending the usefulness of portable machine cutting has been enlarged; and a new page describing a special set-up for templet tracing has been included.

Copies of this 20-page booklet, Form 4062B, can be obtained without cost by writing the nearest office of The Linde Air Products Company or the General Office, 30 East 42nd Street, New York, N. Y.

—STANDARDIZATION—

What it Means to You!

For several years, the principal function of the Resistance Welder Manufacturers' Association has been the standardization of resistance welding machines, transformers and other component parts.

Several standing committees, each working on one group or class of equipment, are constantly considering ways and means of reducing the number of types and varieties of machines, and improving the overall standards concerning them. Definite accomplishments so far include:

Standardization of welding transformer ratings, eliminating odd and unnecessary sizes—which, in turn, reduces the number of patterns, and simplifies manufacturing problems;

Standardization of current regulators;

Standardization of frame sizes, throat depths, electrodes and seam welding wheels, etc.

In all this work, very close cooperation has existed between the Resistance Manufacturers' Association with the American Welding Society and other interested engineering societies.

For your own protection, make sure that all of your future resistance welding machines rigidly comply with adopted standards of

Resistance Welder Manufacturers' Association
505 Arch Street Philadelphia, Pa.

MEMBER COMPANIES

Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Welding Machines Mfg. Company, Detroit, Mich.
Acme Electric Welder Company, Los Angeles, Calif.
American Electric Fusion Corporation, Chicago, Ill.
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Company, Detroit, Mich.
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.
Taylor-Hall Welding Corporation, Worcester, Mass.

ASSOCIATE MEMBER COMPANIES

Electroloy, Inc., New York, N. Y.
Welding Sales and Engineering Co., Detroit, Mich.
P. R. Mallory and Co., Indianapolis, Ind.
S-M-S Corporation, Detroit, Mich.

NEW PRODUCTS

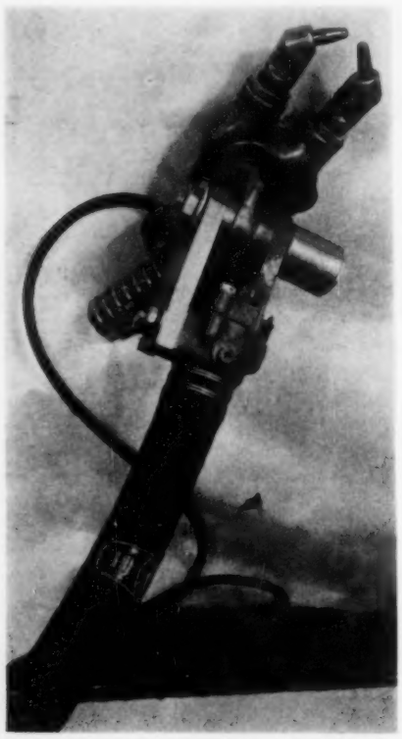
The Society assumes no responsibility for the validity of claims in this Section

PROGRESSIVE ANNOUNCES NEW KICKLESS CABLE

A line of low cost kickless welding cables of "full concentric" design for reduced current loss and with positive and negative current strands wound at steep helical angles to increase ease of flexing and reduce wear is announced by Progressive Welder Co., 3050 E. Outer Drive, Detroit, Mich.

Developed by Progressive in conjunction with Habirshaw Cable & Wire Co., the new "P-H" cables are available in a complete range of capacities to suit almost any portable gun welding used.

The new kickless cables have a rated capacity of 50% in excess of conventional cables of the same size, increased efficiency due to full concentric arrangement of copper, increased life because of extra heavy insulation and marked reduction of wear by external abrasion. Gun handling is thus made easier not only by the kickless feature but also by virtue of the smaller cross section of the cable.



In the above illustration is shown Progressive Welder's new full-concentric cable attached to a gun with a single bolt type of self-locking terminal. The combination of such a terminal, permitting gun swiveling when pressure is not on, reduces effort in handling welding equipment still further in addition to the surprising universally flexible new cable.

The water supply core of the cable consists of $^3/_8$-in. interlocked bronze tubing having high flexibility characteristics. Six current-carrying bundles, of seven copper strands each, enclose this core and are so formed that any flexing causes them to "unwind" rather than bind, as in conventional cables. A heavy reinforced rubber insulating tube separates these inner strands from the outer strands which are also wound at steep helical angle. Between the outer strands and the external, extra-heavy abrasion resistant cable covering is space provided for water circulation.

BLUE GLASS FOR ALUMINUM AND BRONZE WELDING

Alubro-Weld, a blue glass compounded to filter out injurious rays of light in conditions of excessive glare, is a recent scientific development of the Willson Optical Research Laboratories. Alubro-Weld should not be confused with ordinary cobalt-blue glass. It is a special welding glass, specifically recommended for aluminum and bronze welding, glass work, instrument making and other operations where a sodium yellow glare is encountered.

Although Alubro-Weld has a much higher visible light transmission than the average of ordinary blue glass colors, it blocks out the harmful ultra-violet rays entirely and greatly reduces injurious infra-red ray transmission.

NEW ARC-WELDING ELECTRODES

Three new shielded-arc electrodes, Types W-30, W-83 and W-93, for specific types of arc-welding work have been announced by the General Electric Company, as additions to this company's extensive line of electrodes. All three types are heavily coated and will operate on either direct or alternating current.

The Type W-30 is an A. W. S. E-6012 all-position electrode, especially designed for automotive and piece work industries where high currents are desired for high-production speed on lap or fillet welds. This electrode's ability to carry high currents leads to a substantial reduction in stub end losses which ordinarily result from the use of high current.

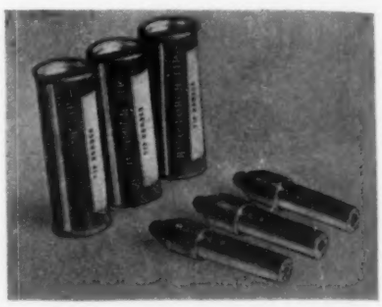
For job welders or manufacturers engaged in the fabrication or repair of cast iron, the Type W-83 is ideally suited. It is an all-position electrode and its outstanding advantage is its ability to operate at relatively low currents, a desirable condition for cast iron.

The Type W-93 is designed for building up steel surfaces to resist wear from shock, abrasion and rolling impact. Its extremely smooth arcing characteristics, freedom from spatter and wide coverage (74 sq. in. per pound) make it well suited for such applications as: agricultural implements, battered rail-ends, snow-plow shoes, crawler-type tractor treads and wheels, and scraper blades.

RIVET WASHING TIPS

These new tips are accurately machined from hard drawn copper with the ratio of the preheat orifices to the oxygen cutting orifice so that maximum preheat and cutting speed are obtained for these operations:

Washing out rivet heads of all types and sizes for repair or reclaiming.
Removing frozen nuts from bolts without damage to the bolt threads.
Removing minor defects in castings.
Hand or machine gougings.



The cutting oxygen stream travels at comparatively low velocity, thus eliminating excessive "blowing" of molten metal. Recommended oxygen pressure on the small size rivets is as low as 15 pounds. This "soft" cutting flame permits the operator to work with greater accuracy, without sacrificing speed or using extra gas.

For further information write to National Cylinder Gas Co., 205 W. Wacker Drive, Chicago, Ill.

WELDING POSITIONER BULLETIN

A new bulletin illustrating and describing improvements in their 3- and 8-ton capacity welding positioners has just been issued by the Industrial Division, Ransome Concrete Machinery Co., Dunellen, N. J.

The bulletin is devoted in part to a comparison between ordinary welds and positioned welds illustrating both and provides a table showing the time required for each type.

The improvements made in the positioners are completely described. They include a T-slotted, all-welded table top, double tilting-gear segments, Timken double roller bearings in main spindle and all-welded steel yoke and base frame. The manufacturer points out that the all-welded construction assures safety to the operator when working under full load conditions.

A copy of the bulletin, Number 176, may be obtained by addressing the company.

IN WELDING CONSTRUCTION TOO

...there's often a better way!

IN these days of constant rush to meet production deadlines, welding engineers in many fields are being called upon to be unusually ingenious — not only in design and fabrication, but in the selection of the steels that will serve each purpose with highest efficiency. Because of new situations, practices which served in ordinary times are being shelved for newer and better ways. Often, success or failure hinges on the selection of a particular steel.

That's the kind of situation where we can often help. For we not only produce the widest variety in Rolled Steels for welding, but have made a complete study of their special characteristics. We can tell you where they will serve best, and how to work them. This knowledge is available to any user of U·S·S Rolled Steels.

With this combination of product and service you can attack any welding problem, completely confident of results. Let us talk with you about your next job. There is a safe possibility that such a talk can result in *helping you find a better way!*

Here are some of the U·S·S Rolled Steels which are contributing much to efficient and economical welded construction.

U·S·S Cor-Ten to resist corrosion.

U·S·S Man-Ten and **Cor-Ten** for weight reduction and corrosion resistance.

U·S·S Abrasion-Resisting Steel for use where abrasive conditions are severe.

U·S·S Heat-Resisting Steels to combat high temperatures.

U·S·S Stainless Steel to resist corrosion of all kinds and reduce structural weight.

U·S·S Carilloy Alloy Steels to carry tremendous bearing pressures.

U·S·S ROLLED STEELS *for* WELDING

CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Export Company, New York

UNITED STATES STEEL

"AMPCO-TRODE"

The coated aluminum bronze welding rod produced by Ampco Metal, Inc., Milwaukee, Wisc., has been re-named "Ampco-Trode." This rod is made with the properties of Ampco Metal, which is well known as a bronze of exceptional wearing ability and largely used in aircraft, machine tools, heavy machinery and similar equipment.

OXYACETYLENE WELDING AND CUTTING EQUIPMENT

A new 12-page, illustrated booklet, "What the Purchasing Agent Should Know About Oxy-Acetylene Welding and Cutting Equipment and Processes," has just been announced by The Linde Air Products Company, a Unit of Union Carbide and Carbon Corporation. The booklet is designed to help the user or prospective user obtain a clear understanding of the oxyacetylene process and the various construction and operating features of welding and cutting apparatus used in applications of the process. It contains a guide to the selection of the proper type of equipment, with a check list of important points to consider in selecting welding and cutting blowpipes, cutting machines, regulators and acetylene generators. Also included is a listing of some of the modern applications of the oxyacetylene flame, suggesting the many uses to which it may be put.

Copies of this booklet, Form 4694, can be obtained without cost by writing the nearest office of The Linde Air Products Company or the General Office at 30 East 42nd Street, New York, N. Y.

SPOT-WELDING TIMERS

Ignitron spot-welding timers to control welding of aluminum, heat-treated alloys and other materials are described in a new leaflet announced by Westinghouse Electric and Manufacturing Company.

Application, distinctive features and construction are discussed. Tubes and other important parts are described. Operating details list the functions of tubes and relays and explain how stepless welding is accomplished. Outline sketches give physical dimensions and show position of conduit connections.

A copy of descriptive data 18-335 may be obtained from department 7-N-20, Westinghouse Electric and Manufacturing Company.

Employment Service Bulletin

POSITIONS VACANT

V-98. Welding Engineer capable of overseeing qualifications, establishing procedures, overseeing production and carrying on sales engineering if found necessary.

V-99. Shop Superintendent and an Engineering-Estimator who are acquainted with the problems of fabricated welded steel structures needed for a new welding division.

SERVICES AVAILABLE

A-405. Experienced X-ray Operator is desirous of a suitable connection for field and shop work.

A-406. Welding Engineer, technical graduate, at present employed, desires change where his talent can be utilized to better advantage. Has had years of experience in supervising design and construction of many complicated structures, through welding. Has an excellent metallurgical background and knows organization, and has been consultant on a number of new developments of varied types. Has been quite successful in instruction of welders.

A-407. Welding Instructor experienced in training men in industry, in trade school, and in adult education, desires welding laboratory instructorship in a collegiate institute in the west by choice. Age 35, married. Seven years' experience including resurfacing, boiler jobbing, and structural equipment welding; and two years of collegiate work (B.S.).

List of New Members

April 1st to April 30, 1941

BOSTON

Crouse, Mayle B. (C), 27 West St., Charlestown, Mass.
Jaeger, George (C), 47 Rosalind Rd., No. Weymouth, Mass.
Pote, Lloyd W. (C), U. S. Navy Yard, Materials Lab., Boston, Mass.

CANADA

McIntyre, A. M. (C), 1 Bain Ave., Toronto, Ont., Canada.

CANAL ZONE

Cole, Harry (C), P.O. Box 735, Diablo Hts., C. Z.
Plath, Arthur C. (D), Box 867, Balboa, C. Z.
Stevens, Charles F. (C), Box 103, Pedro Miguel, C. Z.

CHICAGO

Maher, Frank (D), 4337 W. Jackson Blvd., Chicago, Ill.

CINCINNATI

Raabe, Victor (C), 3447 Cornell Pl., Cincinnati, Ohio.

CLEVELAND

Calamari, Peter L. (C), American Bureau of Shipping, 660 Rockefeller Bldg., Cleveland, Ohio.
Hansford, Thomas E. (C), American Bureau of Shipping, 660 Rockefeller Bldg., Cleveland, Ohio.

COLUMBUS

Adams, Harry E. (C), R.R. 1, So. Charleston, Ohio.
Reuer, George (D), 706 Cypress St., Springfield, Ohio.

DETROIT

Moore, Bruce L. (C), 15453 Hartwell Ave., Detroit, Mich.
Weston, Leslie D. (C), American Bureau of Shipping 1005 Majestic Bldg., Detroit, Mich.
Wood, Lauren P. (B), Stinson Aircraft Div. of Vultee Aircraft, Inc., Wayne, Mich.

INDIANA

Hook, Cleo E. (D), 1608 Home Ave., Columbus, Ind.

KANSAS CITY

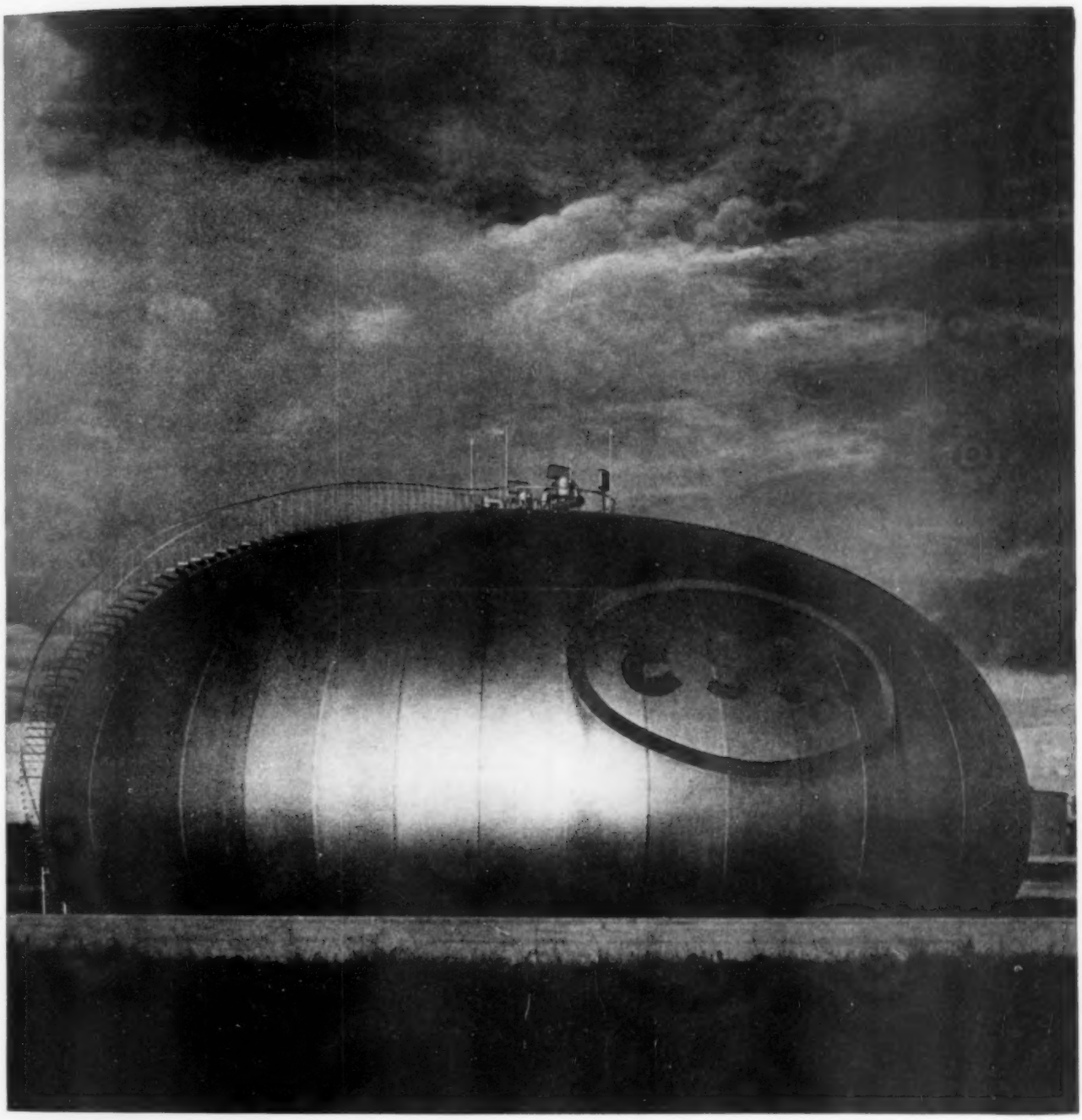
Robb, John D. (B), 3328 Euclid, Kansas City, Mo.

LOS ANGELES

Hutton, Walter C. (C), 1245 Neola St., Los Angeles, Calif.
Jefferson, Reginald L. (B), Los Angeles Shipbldg. & D. D. Corp., San Pedro, Calif.

MARYLAND

Brown, Elisha A. (C), 909 Patapsco Ave., Baltimore, Md.
Carter, Richard A. (C), Gilman Apt. C. 1, 31st & Calvert Sts., Baltimore, Md.
Evans, Stewart A. (C), 214 McKendree Ave., Baltimore, Md.
Jarirnen, Arne A. (C), Bethlehem Steel Co., Sparrows Point, Md.
Kotzelnik, Boyd (C), 2319 Sidney Ave., Baltimore, Md.
Matuszewski, Frank (C), 1508 Olmstead St., Baltimore, Md.
Riley, John H. (C), 110 So. Kossuth St., Baltimore, Md.
Ward, Grady (C), 1317 Herkinner St., Baltimore, Md.



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. . . of welded construction

This steel Hortonspheroid will store 38,000 bbls. of gasoline at 2½ lbs. per sq. in. pressure. It is located at Balboa in the Canal Zone. The seams of pressure vessels must be absolutely tight. Welding makes this condition easy to attain, even where the joints are lapped as they are in this vessel.

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MILWAUKEE

Burzlaff, Orville (D), 1812 Union Ave., Sheboygan, Wisc.
Jacobs, Butler W. (C), 409 Marshall Ave., Milwaukee, Wisc.
Morrissey, P. W. (D), J. I. Case Co., Racine, Wisc.

NEW YORK

Doherty, Edward J. (D), 158 Linden Blvd., Brooklyn, N. Y.
Flanagan, Harold H. (C), 3127—83rd St., Jackson Hts., N. Y.
Vendeleers, A. F. (B), 8811 Elmhurst Ave., Elmhurst, L. I., N. Y.

NORTHERN NEW JERSEY

Burton, Walter H. (C), General Chemical Co., 1100 Line St., Camden, N. J.
Coll, Charles (D), 15 West 48th St., Bayonne, N. J.
Darlington, Donald W. (D), 568 So. 19th St., Newark, N. J.
Fabian, Chester (D), Westinghouse Elec. Elevator Co., 150 Pacific Ave., Jersey City, N. J.
Fahrion, Henry (D), 65 West 17th St., Bayonne, N. J.
Farkas, John (D), 27 West 51st St., Bayonne, N. J.
Guarin, Victor (D), Federal Shipbldg. & D. D. Co., Kearny, N. J.
Majowski, Joseph (D), 120 West 15th St., Bayonne, N. J.
O'Neil, Eugene (D), 5 West 42nd St., Bayonne, N. J.
Rudolph, William (C), Welding Supply Business, 452 Broadway, Paterson, N. J.
Witmeyer, William (C), 49 Forest St., No. Arlington, N. J.

NORTHERN NEW YORK

Ballou, Earl M. (D), 852 Holland Rd., Schenectady, N. Y.
Beck, Francis M. (C), General Elec. Co., Schenectady, N. Y.
Walker, John A. (D), 832 Bridge St., Schenectady, N. Y.

NORTHWEST

Clogston, Charles M. (C), Northern Pump Co., Fridley, Minn.
Tiffany, Raub L. (D), 285 Macalester St., St. Paul, Minn.

PEORIA

Moyer, Herman (C), 313 Bigelow St., Peoria, Ill.

PHILADELPHIA

Corma, Edward (D), 2301 E. Albert St., Philadelphia, Pa.
Metzger, Howard K. (D), Harleysville, Pa.
Reid, Arthur A. (C), Empire Ordnance Co., West Pittston Iron Wks., West Pittston, Pa.

PITTSBURGH

Faust, Leo F. (C), 263 Grand St., Grafton, W. Va.
Hoglund, G. O. (A), The Aluminum Cooking Utensil Co., New Kensington, Pa.

PUGET SOUND

Link, Wm. H. (C), 711—23rd North, Seattle, Wash.

SAN FRANCISCO

Brown, C. E. (D), 1906 Green St., San Francisco, Calif.
Liner, William (D), 2639—39th Ave., Oakland, Calif.
McCulloch, R. B. (B), Anchor Welding Wks., 963 Harrison St., San Francisco, Calif.
Pyles, Guy L. (D), 1558 Willis St., Redding, Calif.
Schoefer, Charles J. L. (B), American Bureau of Shipping, 215 Market St., San Francisco, Calif.
Schwartz, Theodore F. (C), 150 Florida Ave., San Bruno, Calif.
Segal, Mayer (D), 2707 Virginia, Berkeley, Calif.
Sinkevitch, Vitold (D), 4200 Balboa St., San Francisco, Calif.
Wright, Lyman (D), R. 2, Box 85 A, Woodland, Calif.

SOUTH TEXAS

Crawford, A. W. (D), 234 Hathaway, Houston, Texas.
Devine, Jesse (D), 6515 Ave. F, Houston, Texas.
Ginetis, John P. (B), Box 287, Orange, Texas.
Neal, Clyve M. (D), P.O. Box 3, South Houston, Texas.
Roberds, O. C. (D), Hydril Co. of Texas, Houston, Texas.
Werner, George (B), 505 No. Winnetka St., Dallas, Texas.

WESTERN NEW YORK

Neff, John S. (D), 61 Remoleno St., Buffalo, N. Y.
Youngs, K. P. (C), 112 Wardman Rd., Kenmore, N. Y.

YOUNGSTOWN

Voorhees, Franklin E. (D), R.D. 1, Cortland, Ohio.

NOT IN SECTIONS

Berg, Henry L. (D), 801 S. Main, Three Rivers, Mich.
Bishop, Henry R. J. (B), 347 Highlands Rd., Kensington, Johannesburg, South Africa.
Bozarth, G. T. (C), 309 So. Broadway *Park, Lexington, Ky.
Brady, Frank W. (C), 1001 Wyoming Ave., Scranton, Pa.
Brown, Edwin J. (C), Union Wks., 15th & Cascade Sts., Erie, Pa.
Wight, H. Ed. (C), Southeastern Welding Inst., 24 E. Court St., Greenville, N. C.

SECTION ACTIVITIES

BOSTON

At the Annual Meeting of the Boston Section, held on April 16th at Massachusetts Institute of Technology, the following officers were announced as elected to serve for the year 1941–42: *Chairman*, P. L. F. Feyling, Whitehead Metal Products Co. Inc., Cambridge; *Vice-Chairman*, F. W. Davis, E. B. Badger & Sons Co., Boston; *Sec.-Treas.*, P. N. Rugg, Boston Edison Co., Boston; *Directors:* L. I. Dexter, W. B. Strathdee, H. A. Sweet; *Trustee*, A. L. Combs.

CANAL ZONE

The March meeting of the Canal Zone Section was enjoyed by many guests as well as members of the Section. Mr. Wm. J. Mayer, special representative of the A. M. Byers Co. of Pittsburgh, Pa., gave a very interesting talk on the manufacture of wrought iron. Mr. Mayer also showed a five-reel movie on this topic.

Mr. Harry Cole, Structural Engineer with the Panama Canal, Special Engineering Division, addressed the April meeting, on the interesting subject of "The Design of Welded Joints."

CHICAGO

On Saturday, June 21st, the Big Oaks Golf Club, 6600 Lawrence Avenue, Chicago, will be the hosts of the Chicago Section in their Third Annual Golf Tournament.

An over-all charge of $3.50 will include golf privileges all day, as well as lunch and dinner. The Prize Committee announces that there will be plenty of valuable prizes for the hard-working turf-cutters and divot slingers. In addition to the tournament prizes, there will be a blind bogey for out of town guests, door prizes and souvenirs.

Mr. R. E. Long of the Hollup Corporation is General Chairman for the tournament, and he has appointed the following committee chairmen: T. H. Gallagher, Chairman Prize Committee; T. B. Jefferson, Chairman Publicity Committee; W. B. Browning, Chairman Grounds Committee; M. M. Weist, Chairman Ticket Sales Committee; and H. F. Zeigler, Chairman Arrangements Committee.

The last meeting for the season until the fall was held on May 16th. Mr. Leon

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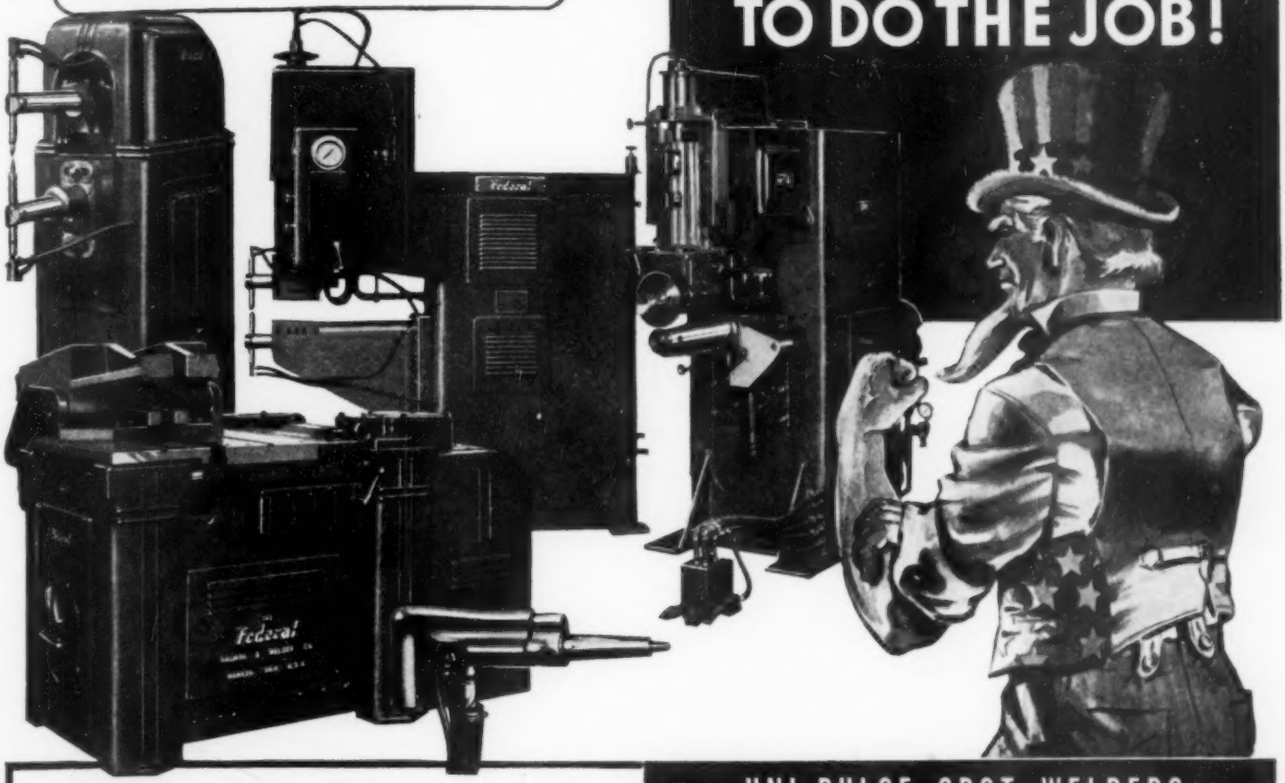
RESISTANCE WELDING

FEDERAL WELDING *Machines* TO DO THE JOB!



● Industries, both large and small, engaged in the gigantic task of assisting Uncle Sam to speed up the output of defense products, find Federal Resistance Welders indispensable on production lines. In the fabricating of both ferrous and non-ferrous metals, Federal Resistance Welding provides strength in excess of standard specifications and substantially reduces production costs. Federal machines in standard and special designs are used extensively by manufacturers of aircraft and such major defense units, as well as in the production of shells, bombs and other auxiliary products.

UNI-PULSE SPOT WELDERS

Employed by the aircraft industry in welding various gauge thicknesses of alloys such as 24 S-T Alclad. Employs electrostatic storage of energy and provides flexible control of current wave form.

COMBINATION SPOT AND PROJECTION WELDERS

Conventional type machines lending themselves to both spot and projection welding operations. Adaptable and in wide demand for many metal fabricating uses.

FEDERAL FLASH WELDERS

Used in operations which necessitate the welding together of abutting ends of two pieces of metal. Strength in excess of parent material developed at place of weld.

FEDERAL SEAM WELDERS

For lap welding sheet stock or for fabricating such articles as various type containers. The welded seam may be either of the "intermittent stitch" type or continuous to render the welded seam gas tight.

★ ★ ★

Avail yourself of Federal engineering facilities and up-to-the-minute counsel without obligation. Let us cooperate with your engineers in designing your product for welding (or fitting the machine to the job).

THE **Federal** MACHINE AND WELDER COMPANY WARREN, OHIO

SALES OFFICES IN ALL PRINCIPAL CITIES

C. Bibber, Welding Engineer, Carnegie-Illinois Steel Co., addressed the meeting on "The Elements of Welded Design." The usual Get-Together Dinner was held at 6:00 P.M. in The Electric Club.

CINCINNATI

The Cincinnati Section has completed a two-lecture series on "Arc-Welding Electrodes."

The April meeting was given over entirely to the chrome-nickel stainless-steel alloy electrode and the lecture was given by Mr. R. D. Thomas, President of Arcos Corporation, Philadelphia, Pa. Mr. Thomas brought out a lot of very important facts regarding the elements that add to or detract from the corrosion resistance qualities of coatings on stainless steel wires.

COLORADO

Mr. T. N. Armstrong of the International Nickel Co. gave an illustrated talk on "Metallurgical Aspects of Welding High Carbon and Alloy Steels" at the May 12th meeting of the Colorado Section, held at the Capitol Insurance Co. Auditorium, Denver.

COLUMBUS

Mr. R. F. Wyer, General Electric Company, was the guest speaker at the May 9th meeting of the Columbus Section. Mr. Wyer spoke on "Atomic-Hydrogen Welding."

CONNECTICUT

Mr. Everett S. Elwood, Welding Engineer, General Electric Co., Bridgeport Works, presented an illustrated talk describing the various resistance welding processes and showed applications of them with the aid of production welded samples, at the April 15th meeting of the Connecticut Section.

DETROIT

The Detroit Section announces a new Chairman and Secretary-Treasurer. They are: *Chairman*, Russell W. Brendle, Great Lakes Eng., Co., River Rouge, Mich.; *Sec.-Treas.*, G. N. Sieger, S-M-S Corporation, Detroit.

The Detroit Section sponsored its first Dinner Dance on May 2nd. It was held in the Colonial Room of the Detroit Leland Hotel, and was attended by over 100 persons, a little less than half of whom were the wives and friends of the members.

The guests of the evening and at dinner were the Past-Chairmen of the Section, the District Vice-President, Mr. Donald Corey, and the National Secretary, Miss M. M. Kelly. An informal reception held preceding the Dinner provided an excellent opportunity for the Section Officers, members and their wives and friends to become acquainted. Following the Dinner, Chairman Sieger called the Roll of Honor which included all the Past-Chairmen of the Detroit Section, who are as follows: H. M. Gould, W. C. Sprau, R. C. Richards, W. A. Woofter, C. A. Bowlus, E. P. Jeffery, M. P. Bailey, R. P. Bailey, W. M. Hayes, J. D. Tebben, Vaughan Reid, D. H. Corey, H. P. Doud.

He then introduced the newly elected officers and Executive Committee members and the National Secretary who expressed her great pleasure at being present at this occasion. In his masterly fashion the Chairman entertained with a few stories after which he called upon Mr. Brendle the newly elected Chairman, to say a few words. The remainder of the evening was given over to a fine program of entertainment and dancing, which lasted until after midnight. Credit for the fine and efficient management of the entire affair goes to Mr. Sieger and his committees. This Dinner Dance rounded out one of the most successful seasons which the Detroit Section has experienced.

LOS ANGELES

A joint meeting with the American Society for Metals was held on April 24th. Dr. V. N. Krivobok of the Lockheed Aircraft Company gave a lecture on "Valuation of Alloy in Elements." Dr. Krivobok's lecture covered very thoroughly the effect of alloying elements on the heat treating of steel. There were 250 in attendance at this meeting.

Officers for 1941–42 were announced at the annual business meeting held in June. They are: *Chairman*, Jim Gowing, Hobart Brothers Co.; *Vice-Chairman*, Francis Stevenson, Vega Airplane Co.; *Sec.-Treas.*, E. O. Williams, Victor Equipment Co.; *Executive Committee:* David Bisbee, Walter Thomas, Roy Tadd, M. R. Dougherty, Howard Newby, Merrill Turner.

MARYLAND

The following men have been elected for the various offices of the Maryland Section for the 1941–42 season: *Chairman*, Roy A. Mansfield; *Vice-Chairman*, Bela M. Ronay; *Sec.-Treas.*, Arthur R. Wynn; *Executive Committee:* J. C. Cumberland, R. Fitzgerald, C. N. Hilbinger Van R. P. Saxe, F. J. Aschenbrenner, W. M. H. Ballantyne, H. N. Boetcher, H. Ross, A. C. Thompson.

MILWAUKEE

The April 25th meeting of the Milwaukee Section was a joint meeting with the Civil Engineers. Mr. Mickey Heath of Radio Station WEMP gave an after-dinner talk on the personnel of the new Milwaukee Brewer baseball team.

Mr. Leon C. Bibber, of the Carnegie-Illinois Steel Corp. presented the welding address on "The Elements of Welded Design."

NEW YORK

The New York Section held its last meeting of the 1940–41 season on Tuesday, May 6, 1941, at 7:30 P.M., in Room 502, Engineering Societies Building, 33 West 39th Street, New York, N. Y.

The election of the following officers for the year 1941–42 was reported: *Chairman*, E. V. David, Air Reduction Sales Co., N. Y.; *First Vice-Chairman*, E. A. Kerbey, Midwest Piping & Supply Co., Inc., N. Y.; *Second Vice-Chairman*, Wayne A. Howard, Socony-Vacuum Oil Corp., Brooklyn, N. Y.; *Sec.-Trans.*, George Sykes, Union Carbide Co., N. Y.; *Executive Committee:* R. E. Bedworth, A. K. Lindquist, G. W. Place, J. F. Randall, G. V. Slottman.

The Technical Chairman of the evening was Mr. John J. Crowe, Assistant to Vice-President and Operating Manager, Air Reduction, New York, N. Y.

The speaker of the evening was Mr. J. H. Deppeler, Chief Engineer, Metal & Thermit Corporation, New York, N. Y., whose topic was "Modern Aspects of Thermit Welding." Following the session, refreshments were served.

NORTHERN NEW JERSEY

Dr. Comfort A. Adams, of the E. G. Budd Manufacturing Company and Past-President of the AMERICAN WELDING SOCIETY, gave a non-technical talk on the present status of welding in industry and the part the AMERICAN WELDING SOCIETY plays in it, at the May 20th meeting of this Section. The program concluded with a social hour and refreshments.

NORTHWEST

The May meeting of the Northwest Section was held on the 7th in the Coffman Memorial Union, University of Minnesota. Mr. A. F. Plant, Vice-President of The Austin Company, Detroit, delivered a very enlightening talk on the subject of "Welding in the Design and Construction of Industrial Plants."

Mr. Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corporation, spoke at the April 22nd meeting on "The Elements of Welded Design." Members of the American Society of Civil Engineers, Minneapolis Engineers Club, and St. Paul Engineers Club were invited to the meeting.

PEORIA

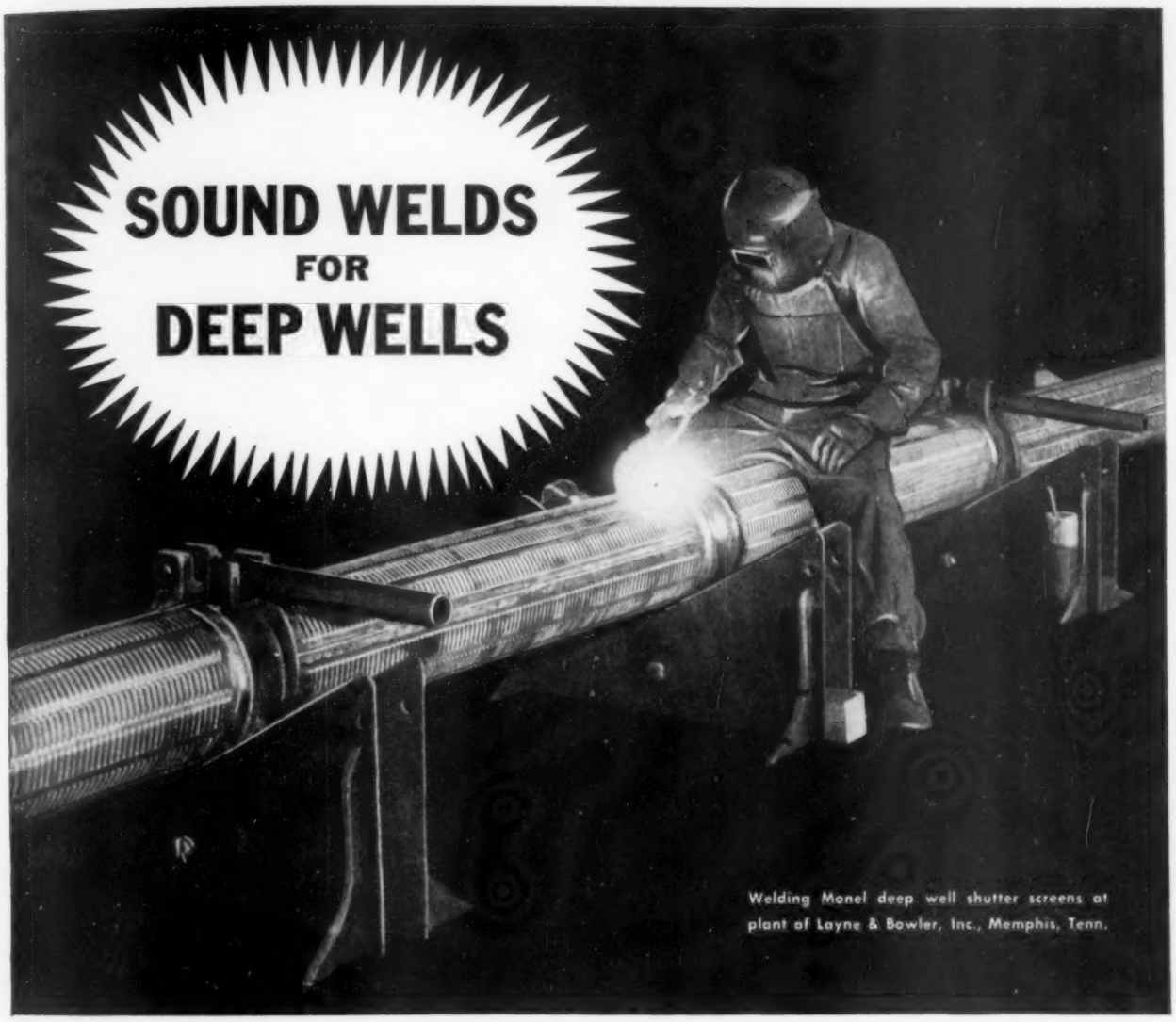
A dinner meeting of the Peoria Section was held on May 7th. Mr. W. F. Schmitt of the Rock Island Illinois Arsenal, spoke on "Arc Welding of Modern Military Equipment." The meeting was very well attended.

PHILADELPHIA

Approximately 175 members and guests attended the April meeting of the Philadelphia Section to hear Mr. L. L. Neebe, Production Engineer of Baldwin Locomotive Works, deliver a fine talk on "The Electric Welding of Railway Equipment." A lively discussion centered around the subject of locked-up stresses.

The Teller's Committee anounced the election of the following officers: *Chairman*, Arthur J. Raymo; *Vice-Chairman*, Harry W. Pierce; *Treasurer*, R. D. Thomas; *Secretary*, K. W. Ostrom; *Executive Committee:* H. R. Salisbury, J. J. Dunne, M. W. Brewster.

Mr. H. E. Hopkins, the retiring secretary, was presented with a beautiful pen



USE OF 130X MONEL METAL ARC WELDING ROD ASSURES SOLID SEAMS THAT RESIST CORROSION

Can welds in Monel be made as sound and resistant to corrosion as the parent metal? Another proof that they *can* is provided by welded Monel shutter screens used in deep well pump installations.

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Do the welds stand up in severe service? One of these Monel screens, 65 feet in length, was examined after 11 years' service under severely corrosive conditions. It showed no trace of corrosion and was put back in service.

One point to remember in electric welding of Monel: Use 130X Monel Metal Arc Welding Rod. For other types of welding use rods recommended in table at right. Helpful information on welding Monel and other high-nickel alloys available on request. Write to:

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Metal Arc . . . No. 130X Monel Metal Arc Welding Rod.

NICKEL

Oxy-Acetylene . . . No. 41 Nickel Gas Welding Rod—no flux is used.

Metal Arc . . . No. 131 Nickel Metal Arc Welding Rod.

INCONEL

Oxy-Acetylene . . . No. 42 Inconel Gas Welding Rod—Inconel Gas Welding Flux.

Metal Arc . . . No. 132 Inconel Metal Arc Welding Rod.

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and pencil set as a token of the Section's appreciation of his twenty years of continued service.

PITTSBURGH

The Fourth Annual Tri-State Welding Conference held by the Pittsburgh Section, Friday, April 18th, demonstrated again that these Welding Conferences are rapidly becoming recognized as the outstanding Technical meetings of the year.

Mr. J. F. Lincoln, President of the Lincoln Electric Co., and Mr. J. Lyell Wilson of the American Bureau of Shipping were the afternoon speakers and gave most interesting discussions on their subjects, "Welding Profits *vs.* Prejudice" and "Welding in the Shipbuilding Industry." Both subjects were illustrated with slides following which the meeting was thrown open for discussion.

The Conference, in charge of retiring Chairman Geo. F. Wolfe, Dravo Corporation, was carried on in his usual capable manner.

Colonel G. F. Jenks, President of the AMERICAN WELDING SOCIETY, was introduced at the Afternoon Session as was Mr. Wm. Spraragen, New York Technical Secretary, both of whom spoke a few works on behalf of the work the A. W. S. is doing.

Preceding the principal talk of the evening by Colonel G. F. Jenks, Ordnance Department, U. S. A., Chairman William Whigham, Jr., of the Engineers Society of Western Pennsylvania, with which Society this Conference was held jointly, gave a talk on coordinating the efforts by the many Technical Societies in the Pittsburgh district to the end that fewer and better meetings be held in the future.

The "get-to-gether" dinner between sessions turned out to be an "overflow" affair and it became necessary to find additional space for the many who attended.

ROCHESTER

The May 1st meeting of the Rochester Section was one of the best attended meetings. Mr. James F. Lincoln, President of The Lincoln Electric Co., spoke on the lively subject of "Welding Profits *vs.* Prejudice."

The annual election of officers was held at this meeting and the following elections were announced: *Chairman*, Wm. Conley; *Vice-Chairman*, Robert Cattanach; *Sec.-Treas.*, P. W. James; *Executive Committee:* W. G. Dick, Paul Eckland, E. G. Habel, E. L. Hand, W. J. Schmitt.

ST. LOUIS

Mr. E. W. P. Smith, Vice-President of The Lincoln Electric Co., was the guest speaker at the May 9th meeting. His subject was on "Welding Costs—Their Control and Calculation."

SAN FRANCISCO

The regular monthly meeting of this Section was held on April 25th. Mr. C. E. Grant, Supervisor of Applied Engineering Dept., Air Reduction Sales Company, showed slides on "The Oxyacetylene Process in Industry," as it is being used today to speed up defense work in shipyards, railroad shops and industrial plants, illustrating welding, cutting and nicking.

SOUTH TEXAS

The South Texas Section had a most interesting meeting April 25th at the Texas State Hotel in Houston, and more than one hundred members and guests were present. Mr. S. S. Scott, Welding Engineer for the Shipbuilding Division of Consolidated Steel Corp., Orange, discussed "Welding in Shipbuilding and Operation," and presented a high-speed motion-picture film showing conditions that surround the arc during welding operations. The Consolidated Company laid the keel of the first of several destroyers to be built for the Federal Government on May 15th, and approximately one thousand welding operators will be needed in the plant within the year.

TULSA

Mr. C. W. Metzger, of the Haynes Stellite Company, Kokomo, Indiana, addressed the May 9th meeting of this Section, on the subject "Hard Facing" with two reels of motion pictures, which was followed by a round-table discussion.

WASHINGTON

The last meeting of the Washington Section for the year 1940–41 was held on April 29, 1941. Approximately 135 members attended the banquet at the Harrington Hotel, and though the turkey and trimmings were of primary interest, the group was favored by having the presence of a number of past-presidents of the national organization, Colonel G. F. Jenks, President, and last but not least, officers of the Local Section. Bill Spraragen was present to represent the New York office, and Colonel Jenks acquainted the group with activities of the national organization.

Chairman Trexel introduced the honor guests and officers of this Section for the year 1941–42, after which Mr. A. G. Bissell presented Chairman Trexel with his past-chairman's pin. Mr. R. B. Swope, Chairman-Elect for the forthcoming year, solicited support of the membership and guests for the activities of next year. Mr. R. F. Wood, Treasurer, delivered his annual report which shows that the Local Section is well equipped financially for continuing a program of expansion and interest in welding.

Following the banquet the meeting adjourned to the Department of Commerce Auditorium where Mr. W. H. Reger entertained with the General Electric "House of Magic." Mr. L. H. B. Peer assisted. About 400 people attended, among which were many wives and children of welders.

WESTERN NEW YORK

This Section met April 18th, in the Hotel Buffalo, for the regular April dinner and business meeting.

Mr. H. R. Pufahl of The Linde Air Products Co. gave a very interesting talk on "Modern Developments in Oxyacetylene Cutting Machines with Multiple Nozzle Operation." The preparation of plate edges for welding was the main topic, followed by moving pictures showing the welding of plates by the Unionmelt process.

WICHITA

Mr. Orville T. Barnett, Metallurgist, Metal & Thermit Corp., Jersey City, N. J., was the guest speaker at the April 9th meeting The subject of his talk was "Procedure Control of Welding" which was illustrated with slides. Mr. Barnett's talk was well received by the members present.

YORK-CENTRAL PENNSYLVANIA

The April meeting of the York-Central Pennsylvania Section was held on the 16th. Mr. W. B. Lair, Welding Engineer of the York Safe and Lock Company, presented a short talk covering the various welding methods; temperatures involved, rates of heating, rates of cooling, etc. This was followed by a fifteen minute discussion period, designed especially for operators, but actually was of much interest to the whole group.

Mr. F. G. Outcalt of The Linde Air Products Company addressed the group on the "Unionmelt Welding Process." This talk was illustrated by very fine moving pictures, some of which were shown for the first time. Mr. Outcalt's talk and subject were most interesting and a great deal of discussion followed.

The May meeting was held on the 14th. The principal speaker, Mr. Howard Miller of the Republic Steel Corporation, spoke on the timely subject of "Welding in National Defense." The preliminary talk for welding operators was given by Mr. Eli Anderson of the York Ice Machinery Company.

YOUNGSTOWN

The final meeting of the season was held in the Auditorium of the Ohio Edison Building, on May 6th. Report on the financial situation of the Section was given by the Secretary, which was quite satisfactory. Report by the Chairman of the Membership Committee was also given and it was found that the growth of the Section has been quite rapid. During the past season the membership has increased by approximately 50%.

Report on the election of officers was given with the following results: *Chairman*, Robert Haas, Lincoln Electric Co.; *Vice-Chairman*, Robert Poole, Truscon Steel Co.; *Sec.-Treas.*, E. J. Del Vecchio, Taylor-Winfield Corp.

Mr. J. G. Magrath of the Air Reduction Sales Co. presented a very fine talk, generously illustrated with slides, on the subject of "Flame Machining."

Mr. J. H. Zimmerman of The Linde Air Products Company spoke on the subject of "Flame Cutting." His talk was also illustrated with slides.

Mr. K. F. Shattel of National Cylinder Gas Company was the third speaker on the program. Mr. Shattel spoke on the subject of "Flame Hardening."

SHORT-SHORT STORY ON "FP"
—versatile, new, high-speed electrode.
POSITIONS: Horizontal fillet, vertical, overhead and downhand welding.
TYPES OF WORK: Low or medium carbon steel fabrication; especially good for loose fit-ups.
COATING: Tough, non-absorbent coating permits reasonable bending without cracking.
DIAMETERS: Standard from 3/32" to 3/8".
LENGTHS: All diameters in 14" length; four largest also in 18" length.
MEETS CODE REQUIREMENTS of A.W.S. and A.S.T.M. Tentative Electrode Specifications for Classifications E6012 and E6013. Also A.S.M.E. Boiler Code paragraph U69. Approved by American Bureau Shipping for Hull, Class 1 and Boiler, Class 1, all positions.

Get acquainted with F.P.

. . . SAY GOOD-BYE TO A LOT OF COMMON WELDING TROUBLES!

Here's an electrode that's NEWS—NEWS because it makes available for the first time an electrode developed especially for your own precision manufacturing operations—NEWS, because it gives a new type of all-round welding performance.

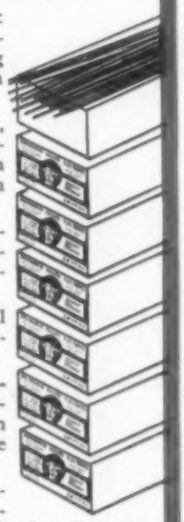
Designed especially for horizontal fillet welding, the new Westinghouse **FLEXARC FP** electrode can be used equally well for vertical, overhead or downhand welding.

FP cuts costs by reducing excessive spatter loss, especially at high current rates. **FP** works equally well with either a-c or d-c. Crater blisters and slag pits are reduced—even the first pass with an **FP** rod lays down flat and smooth.

Free Electrode Wall Chart

Check the characteristics of this and other new Westinghouse electrodes. Ask for FREE copy of the Westinghouse Electrode Chart. It makes ordering easy—and contains some mighty useful information for the man on the job. Ask for WC-426. WESTINGHOUSE ELECTRIC & MANUFACTURING CO., East Pittsburgh, Pa., Dept. 7-N.

Handy Westinghouse "Shopping List" for Electrode Buyers



FlexArc FP—For fillet position and general purpose high-speed welding on low-to-medium carbon steels. A-c or d-c.

FlexArc DH—For heavy, high-speed, flat or horizontal fillet welding on low-to-medium carbon steels. A-c or d-c.

FlexArc AP—For all position welding on low-to-medium carbon steels. Reverse polarity d-c.

FlexArc SW—For general purpose, all position welding. A-c or d-c.

Castingweld and Free-machineweld—For welding any type of iron casting. Latter type can be machined.

Hardentough—For hard-surfacing parts of machinery and equipment. Grades for all needs.

FOR SPECIAL APPLICATIONS—*Nickelchromeight, Nickelchromtwelve, Nickelmang, Bronzark.*

J-21166

Westinghouse

FLEXARC ELECTRODES

TENTATIVE PROGRAM

TWENTY-SECOND ANNUAL MEETING AMERICAN WELDING SOCIETY WEEK OF OCTOBER 19, 1941

Headquarters: BELLEVUE-STRATFORD HOTEL, PHILADELPHIA, PA.

Make Room Reservations Early—Direct with Bellevue-Stratford Hotel

Arrive Sunday 19th—(Convention Hotel) Rates Apply for Short or Long Stay

National Metal Exposition, Commercial Museum—Open Afternoons and Evenings Throughout the Entire Week, Commencing October 20, 1941

IMPORTANT

ALL Technical Sessions will positively start on time.

No Stenotype Reporter—Members desiring to discuss papers are urgently requested to prepare discussion in writing in advance of the meeting and to send copies to headquarters as those preparing written discussion will be given preference at the sessions. Members and guests giving extemporaneous discussion at meeting should forward a written transcript of discussion as soon as possible after the meeting.

Members and guests are urged to REGISTER immediately upon arrival at A. W. S. HEADQUARTERS and obtain Convention Badge admitting them to Exposition.

NO REGISTRATION FEE but a charge of $1.00 (per member) and $1.50 (non-member) is made for Technical Sessions Papers.

Registration hours throughout the week:

Bellevue-Stratford Hotel

Monday, Tuesday and Wednesday	9 A.M. to 5 P.M.
Thursday	9 A.M. to 7 P.M.
Friday	9 A.M. to 12 Noon

Commercial Museum

Monday, Tuesday and Wednesday	12 Noon to 10 P.M.
Thursday	12 Noon to 6 P.M.
Friday	9 A.M. to 10 P.M.

SUNDAY, OCTOBER 19th, 5 to 7 P.M.

PRESIDENT'S RECEPTION

MONDAY, OCTOBER 20th, Morning—9:30 A.M.

OPENING SESSION

Co-Chairmen

G. F. JENKS, President, American Welding Society
E. V. DAVID, Chairman, Convention Committee

PRESENTATION OF MEDALS AND PRIZES

TECHNICAL SESSION—10:15 A.M.

WELDABILITY OF PLAIN CARBON AND LOW-ALLOY STEELS

Co-Chairmen

O. B. J. FRASER, Chairman, Meetings and Papers Committee
C. H. JENNINGS, Westinghouse Electric & Manufacturing Company

The Specification of Weldability of Steels
by A. B. KINZEL, Union Carbide and Carbon Res. Labs.

Weldability Tests of Nickel Steels
by C. E. JACKSON and G. G. LUTHER, Naval Research Lab.

Weldability of Steels
by W. H. BRUCKNER, University of Illinois

OPENING METALS EXPOSITION—12:00 Noon

Monday Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

RESEARCH—NON-FERROUS

Co-Chairmen

J. R. DAWSON, Union Carbide & Carbon Res. Labs.
R. B. SWOPE, Southern Oxygen Company

Study of the Effect of Core Wire Temper on the Quality of Welds in Monel, Nickel and Inconel
by F. G. FLOCKE, K. M. SPICER and T. E. KIHLGREN, The International Nickel Co., Inc.

The Flow of Metal in Brazing Aluminum
by Dr. M. A. MILLER, Aluminum Research Labs.

Welding of Copper
by A. P. YOUNG, Michigan College of Mining & Technology

Spot Welding of Nickel and Its Alloys
by W. F. HESS and ALBERT MULLER, Rensselaer Polytechnic Institute

The Contact Resistance of Pure Aluminum in Resistance Welding
by W. B. KOUWENHOVEN, Dean, The Johns Hopkins University

SHIPBUILDING

Co-Chairmen

DAVID ARNOTT, American Bureau of Shipping
T. M. JACKSON, Sun Shipbuilding & Dry Dock Co.

Riveted vs. Welded Galvanized and Corrosion Resisting Steel Smoke Pipes
by H. O. KLINKE, U. S. Navy Yard

Machine Flame Cutting in Ship Construction
by E. R. McCLUNG and H. L. WAGENER, New York Shipbuilding Corp.

Survey of Welding and Cutting in Ship Construction
by F. G. OUTCALT and J. M. KEIR, The Linde Air Products Company

Welding Applications in Naval Machinery
by H. W. HIEMKE and J. D. BERT, Navy Department, Bureau of Ships

RAILROAD

Co-Chairmen

A. G. OEHLER, Associate Editor, *Railway Age*
J. W. SHEFFER, American Car & Foundry Company

Welding as Applied to Locomotive
by JAMES PARTINGTON, American Locomotive Company

Some Engineering Observations on Welded Railroad Rolling Stock
by H. M. PRIEST, Railroad Research Bureau

Welding Locomotives
by A. J. RAYMO, Baldwin Locomotive Co.

Pressure Butt Welding of Railroad Rails
by LEM ADAMS, Oxweld Railroad Service Co.

Evening—7:30 P.M.

Industrial Research Conference—G. F. JENKS, **Chairman**, presiding

TUESDAY, OCTOBER 21st, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

FUNDAMENTAL RESEARCH—ARC STUDIES AND HEAT FLOW

Co-Chairmen

F. C. FYKE, Standard Oil Development Co.
H. R. SALISBURY, Air Reduction Sales Co.

Magnetic Arc Blow
by C. H. JENNINGS and A. B. WHITE, Westinghouse Electric & Mfg. Co.

Mechanism of Metal Transfer in the Arc
by L. J. LARSON, Consulting Engineer

Heat Flow in Arc Welding
by F. M. MAHLA, M. C. ROWLAND and G. E. DOAN, Lehigh University

TRAINING

Co-Chairmen

A. G. BISSELL, Bureau of Ships, Navy Dept.
A. F. DAVIS, The Lincoln Electric Company

Roundtable discussion on **Training of Welding Operators** led by A. G. BISSELL

A. W. S. Minimum Requirements for the Training of Welding Operators
by A. B. WRIGLEY, Chairman of Committee

Training Welders for National Defense
by JAMES A. WALN, Agent, Trade and Industrial Education, Defense Training Program, U. S. Office of Education

Training of Oxyacetylene Welding and Cutting Operators
by D. E. ROBERTS, The International Acetylene Association

Tuesday Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

FUNDAMENTAL RESEARCH—TESTING METHODS

Co-Chairmen

H. C. BOARDMAN, Chicago Bridge and Iron Co.
E. I. BRADY, Alloy Rods Corporation

Weld Inspection by Means of Infra-Red Light
by Prof. W. T. TIFFIN, University of Oklahoma

AIRCRAFT AND AUTOMOTIVE

Co-Chairmen

C. L. EKSERGIAN, Budd Wheel Company
PETER ALTMAN, Vultee Aircraft, Inc.

Automotive Welding
by S. M. SPICE, Buick Motor Division, VAUGHN FEGLEY, A-C Spark Plug Co., and L. M. SKIDMORE, General Motors Institute of Technology

STRUCTURAL

Co-Chairmen

H. W. LAWSON, Bethelehm Steel Company
W. F. CARSON, Consulting Engineer

Structural Welding
by VAN RENSSELAER P. SAXE, Consulting Engineer

TUESDAY, OCTOBER 21st, Afternoon *(Continued)*

FUNDAMENTAL RESEARCH—TESTING METHODS *(Continued)*

Evaluating Welded Joints
by Prof. W. F. HESS, Rensselaer Polytechnic Institute

Methods of Testing Spot Welds
by R. E. BOWMAN, War Department, Air Corps

Thermal Gradients in Spot-Welding Electrodes
by Dr. F. R. HENSEL, E. I. LARSEN and E. F. HOLT, P. R. Mallory & Co.

AIRCRAFT AND AUTOMOTIVE *(Continued)*

Production and Quality Control in Aluminum Alloy Spot Welding
by P. H. MERRIMAN, The Glenn L. Martin Company

Development of Welding in Aircraft Industry
by FRANK SMITH, Stout Skycraft, Inc.

Condenser Discharge Welding of Aluminum Alloys
by JOHN W. DAWSON, Raytheon Mfg. Co., and B. L. WISE, Federal Machine & Welder Co.

STRUCTURAL *(Continued)*

Design of a Welded Bridge
by G. T. HORTON, Chicago Bridge & Iron Co.

Adapting Design and Construction Methods to Welding
by LaMOTTE GROVER, Air Reduction Sales Company

Cleveland Liquefied Gas Storage Tanks
by J. O. JACKSON, Pittsburgh-Des Moines Steel Co.

Structural and Bridge Welding
by R. E. SPAULDING, The Aetna Steel Construction Co.

Evening—7:30 P.M.

Fundamental Research Conference—H. C. BOARDMAN, **Chairman**, presiding

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WEDNESDAY, OCTOBER 22nd, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

RESEARCH—STRUCTURAL

Co-Chairmen

K. L. HANSEN, Harnischfeger Corporation
G. V. SLOTTMAN, Air Reduction Sales Company

Tests of Miscellaneous Types of Welded Building Connections
by BRUCE JOHNSTON and G. R. DEITS, Lehigh University

An Investigation of Welded Connections for Axially Loaded Angle Members
by G. J. GIBSON and B. T. WAKE, American Bridge Company

AUTOMOTIVE AND AIRCRAFT

Co-Chairmen

CARL DeGANAHL, Fleetwings, Inc.
J. D. TEBBEN, P. R. Mallory & Co.

Welding in Aircraft Construction and Maintenance
by A. K. SEEMANN, The Linde Air Products Co.

Management Control of Design and Welding of Aircraft
by J. P. DODS, Summerill Tubing Co.

Stored Energy Resistance Welding as Applied to Aircraft
by L. P. WOOD, Curtiss-Wright Corp., Airplane Division

Wednesday Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

RESISTANCE WELDING SYMPOSIUM

Co-Chairmen

L. W. CLARK, The Detroit Edison Company
R. E. POWELL, Western Electric Company

Structural and Metallurgical Properties of Stored Energy Welds
by G. S. MIKHALAPOV, Taylor Winfield Corp.

Pulsation Welding of Heavy Structures
by O. C. FREDERICK and R. P. McCANTS, General Electric Co.

The Electrical Characteristics of Resistance Welders and Proximity Effect of Magnetic Work Materials
by J. H. COOPER, Taylor Winfield Corp.

Power Control
by H. R. CRAGO, General Electric Company

Forging Welding
by L. M. BENKERT, Progressive Welder Company

Spot-Welding Control and Supervision
by J. R. FETCHER, E. G. Budd Mfg. Co.

FUNDAMENTAL RESEARCH—METALLURGICAL

Co-Chairmen

H. O. HILL, Bethlehem Steel Company
MILTON MALE, U. S. Steel Corporation of Delaware

The Effect of Plate Temperature and Variable Wind Velocities of Properties of Carbon-Steel Metal Arc Welds
by JOHN L. MILLER and E. L. KOEHLER, Illinois Institute of Technology

Welding Aluminum Deoxidized and Aluminum-Containing Steels
by C. E. SIMS and F. B. DAHLE, Battelle Memorial Institute

Fabricated Non-Ferrous Electrodes for Welding Gray Cast Iron
by W. A. SPINDLER, University of Michigan

Notch Sensitivity of Welds Under Repeated Loading
by H. L. DAASCH, University of Vermont

NATIONAL DEFENSE

Co-Chairmen

E. A. DOYLE, The Linde Air Products Company
C. A. LOOMIS, Bureau of Ships, Navy Department

Low Temperature Brazing in National Defense Projects
by LEO EDELSON, Handy & Harman

Billet Cutting for Steel Forgings
by H. E. ROCKEFELLER, The Linde Air Products Co.

Austenitic Welding for Defense Equipment
by R. D. THOMAS, JR., Arcos Corp.

Machine Cutting in National Defense Work
by R. F. HELMKAMP and A. H. YOCH, Air Reduction Sales Company

Welding Ordnance Equipment
by G. F. JENKS, Ordnance Department, U. S. Army

THURSDAY, OCTOBER 23rd, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

RESISTANCE WELDING

Co-Chairmen

J. D. GORDON, Taylor Winfield Corporation
E. C. SMITH, National Electric Welding Machines Co.

The Effect of Condition of the Surface on the Contact Resistance of Carbon Steel in Resistance Welding
by W. B. KOUWENHOVEN, Dean, The Johns Hopkins Univ.

Spot-Welding Characteristics of Various Materials
by A. M. UNGER, Pullman-Standard Car Mfg. Co.

Electrical Measurement of Electrode Pressure and Travel During Spot Welding
by W. F. HESS and L. DANIEL RUNKLE, Rensselaer Polytechnic Institute

Effect of Contact Resistance in Spot Welding
by FRANK J. STUDER, Union College

MACHINERY

Co-Chairmen

C. I. MacGUFFIE, General Electric Company
A. J. RAYMO, Baldwin Locomotive Works

Flame Hardening Internal and External Round Surfaces
by STEPHEN SMITH, Air Reduction Sales Company

Uses of Flame-Hardening in Machine-Tool Production
by A. L. HARTLEY, R. K. LeBlond Machine Tool Co.

Welding of Cast Steel from Steel Foundryman's View-Point
by T. H. BOOTH, Walworth Co.

Afternoon—2:00 P.M.

COMMITTEE MEETINGS
AND
DISTRICT AND SECTION OFFICERS CONFERENCE

No technical sessions are scheduled in order that the A. W. S. members and guests may have time to leisurely view the exhibits.

Evening—7:00 P.M.

ANNUAL BANQUET

FRIDAY, OCTOBER 24th, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

PIPING AND PRESSURE VESSELS

Co-Chairmen

D. H. COREY, Detroit Edison Company
R. B. CLEMENTS, The Linde Air Products Co.

Flame Preheating and Stress-Relieving Arc-Welded High-Pressure Pipe Lines
by P. T. ONDERDONK and WERNER PETERSON, Consolidated Edison Company of New York

Welding Pressure Vessels, Tanks and Heat Exchangers
by H. B. SCHLOSSER, Edge Moor Iron Works

Technique of X-Ray Examination of Heavy Drum Plate
by O. R. CARPENTER, Babcock and Wilcox Company

WELDING OF HIGH-ALLOY STEELS

Co-Chairmen

R. D. THOMAS, Arcos Corporation
L. H. CHRISTENSEN, Reid Avery Company

Hardness Measurements on Rolling Steel That Contained Welds
by J. T. PHILLIPS, Foster Wheeler Co.

The Shotweld Process of Welding Stainless Steel
by Dr. JOSEPH WINLOCK and J. J. MacKINNEY, E. G. Budd Manufacturing Company

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BUSINESS MEETING—11:30 A.M.

Chairman—G. F. JENKS
President, American Welding Society

Annual Report of the President Election and Installation of 1941–42 Officers

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Board of Directors' Luncheon Meeting

Sections—CHAIRMEN, SECRETARIES AND REGULAR MEETING DATES

BIRMINGHAM 3rd Fri.
CHAIRMAN—C. R. TINSLEY, U. S. Pipe & Foundry Co., Bessemer, Ala.
SECRETARY-TREAS.—W. L. POOLE, Air Reduction Sales Company, 2825 No. 29th Ave., Birmingham, Ala.

BOSTON 2nd Mon.
CHAIRMAN—P. L. P. FEYLING, Whitehead Metal Products Co., Inc., Cambridge, Mass.
SECRETARY—P. N. RUGG, 8 Eastern Ave., Wakefield, Mass.

CANAL ZONE 1st Tues.
CHAIRMAN—R. E. HOLLICK, Box 1146, Ancon, Canal Zone
SECRETARY-TREAS.—JAMES G. MURRAY, P. O. Box 623, Diablo Hts., Canal Zone

CHATTANOOGA, TENN. 1st Wed.
CHAIRMAN—MARK HOLT, Chattanooga Welding & Machine Co., Chattanooga, Tenn.
SECRETARY—M. T. GLENN, 242 Oak Street, Chattanooga, Tenn.

CHICAGO 3rd Fri.
CHAIRMAN—A. M. UNGER, Pullman-Standard Car Mfg. Co., Chicago, Ill.
SECRETARY—M. S. HENDRICKS, Welding Engineer, Room 731, 506 South Wabash Avenue

CINCINNATI, OHIO
CHAIRMAN—ERIC O'HARA, Cincinnati Gas & Elect. Co., Cincinnati, Ohio
SECRETARY—R. G. FUGATE, Williams & Co., Inc., Cincinnati, Ohio

CLEVELAND 2nd Wed.
CHAIRMAN—J. F. MAINE, Republic Structural Iron Works, Cleveland, Ohio
SECRETARY-TREAS.—A. LESLIE PFBIL, Universal Power Corporation, Cleveland, Ohio

COLORADO 3rd Wed.
CHAIRMAN—J. H. JOHNSON, Johnson Supply Co., Denver, Colo.
SECRETARY-TREAS.—H. W. CREAGER, Hendrie & Bolthoff Mfg. & Supply Co., Denver, Colo.

COLUMBUS, OHIO 2nd Fri.
CHAIRMAN—J. A. FOUST, Ohio State University, Columbus, Ohio
SECRETARY—G. S. HERREN, The Seagrave Corp., Columbus, Ohio

CONNECTICUT 1st Tues.
CHAIRMAN—J. S. MILLER, New York, New Haven & Hartford R. R., New Haven, Conn.
SECRETARY—B. H. PERRY, Hartford Elec. Steel Co., 540 Flatbush Ave., Hartford, Conn.

DETROIT 1st or 2nd Fri.
CHAIRMAN—R. W. BRENDLE, Great Lakes Eng. Co., River Rouge, Mich.
SECRETARY—G. N. SIEGER, S. M. S. Corp., 1165 Harper Ave., Detroit, Mich.

GEORGIA 1st Fri.
CHAIRMAN—RALEIGH DRENNON, 357 W. Peachtree St. N. E., Atlanta, Ga.
SECRETARY—EDWARD GUILLOTT, 282 Spring St. N. W., Atlanta, Ga.

HAWAII Last Thurs.
CHAIRMAN—ROBERT A. PLAUS, W. A. Ramsay, Ltd., Honolulu, T. H.
SECRETARY—ALAN G. SLIPPER, Hawaiian Gas Products Co., P. O. Box 2454, Honolulu, T. H

INDIANA
CHAIRMAN—WAYNE H. MCGLADE, J. D. Adams Mfg. Co., Indianapolis, Ind.
SECRETARY—E. F. GILYEAT, JR., J. D. Adams Mfg. Co., 217 So. Belmont Ave., Indianapolis, Ind.

KANSAS CITY, MO. 3rd Mon.
CHAIRMAN—N. ASHTON, Howard, Needles Tammen, & Bergendoff Kansas City, Mo.
SECRETARY— L. MORGAN, 18 W. 59 St. Kansas City, Mo.

LAKE SHORE
CHAIRMAN—A. W. WIEMANN, Armour Leather Co. Sheboygan, Wis.
SECRETARY—R. E. KING, 1308-A Hamilton St. Manitowoc, Wis.

LOS ANGELES 3rd Thurs.
CHAIRMAN—J. C. GOWING, Hobart Brothers Co., 1708 So. Soto St., Los Angeles, Calif.
SECRETARY—E. O. WILLIAMS, Victor Equipment Co., Los Angeles, Calif.

LOUISIANA 1st Fri.
New officers not yet selected.

MARYLAND 3rd Fri. except April
CHAIRMAN—R. A. MANSFIELD, Southern Oxygen Co., Baltimore, Md.
SECRETARY-TREAS.—ARTHUR WYNN, 13 No. Hill Road, Baltimore, Md.

MILWAUKEE 3rd. Fri.
CHAIRMAN—R. E. BOECK, 3889 N. 4th St., Milwaukee, Wis.
SECRETARY—GILBERT F. MEYER, Machinery & Welder Corp., Milwaukee, Wis.

NEW YORK 2nd Tues. except when Joint Meeting is held
CHAIRMAN—E. V. DAVID, Air Reduction Sales Co., 60 E. 42nd St., N. Y. C.
SECRETARY—GEORGE SYKES, Union Carbide Co., 30 E. 42nd St., N. Y. C.

NORTHWEST 3rd Wed.
CHAIRMAN—T. P. HUGHES, University of Minn., Minneapolis, Minn.
SECRETARY—ALEXIS CASWELL, Manufacturers' Assoc. of Minn., 200 Builders Exchange Bldg., Minneapolis, Minn.

NORTHERN NEW JERSEY
CHAIRMAN—F. C. FYKE, Standard Oil Development Co., Elizabeth, N. J.
SECRETARY—H. S. CARD, 449 Elmora Ave., Elizabeth, N. J.

NORTHERN N. Y. Last Thurs.
CHAIRMAN—W. C. HUTCHINS, General Electric Co., Schenectady, N. Y.
SECRETARY—W. W. CHURCHILL, General Electric Co., Schenectady, N. Y.

OKLAHOMA CITY 1st Fri.
CHAIRMAN—C. C. WILLIS, Oklahoma Gas & Electric Co., Oklahoma City, Okla.
SECRETARY—Wm. T. TIFFIN, University of Oklahoma, Norman, Okla.

PEORIA—CENTRAL ILLINOIS
CHAIRMAN—WALTER J. BROOKING, R. G. Le Tourneau Inc., Peoria, Ill.
SECRETARY—ALBERT A LOSCH, R. G. Le Tourneau, Inc., Peoria, Ill.

PHILADELPHIA 3rd Mon.
CHAIRMAN—A. J. RAYNO, Baldwin Locomotive Wks., Philadelphia, Pa.
SECRETARY—K. W. OSTROM, Arcos Corp., 401 N. Broad St., Phila., Pa.

PITTSBURGH Middle Wed.
CHAIRMAN—G. F. WOLFE, Dravo Corp., Engineering Wks. Div., Pittsburgh, Pa.
SECRETARY—J. F. MINNOTTE, Minnotte Bros., 1201 House Bldg., Pittsburgh

PUGET SOUND
CHAIRMAN—G. M. MCBRIDE, Air Reduction Sales Co., 3623 East Marginal Way, Seattle, Washington
SECRETARY-TREAS.—R. S. RUSSELL, Hydraulic Supply Co., 7500—8th Ave. South, Seattle, Wash.

QUAD CITIES
CHAIRMAN—A. R. GUSTAFSON, 840 Third Ave., Moline, Illinois
SECRETARY—J. W. SHUGARS, Lincoln Elec. Co., Moline, Illinois

ROCHESTER, N. Y. 1st Thurs.
CHAIRMAN—WM. CONLEY, Univ. of Rochester, River Campus, Rochester, N. Y.
SECRETARY—PAUL W. JAMES, Lincoln Electric Co., 65 Lancaster St., Rochester, N. Y.

SAN FRANCISCO Last Fri.
CHAIRMAN—H. CHANEY, Bethlehem Steel Co., San Francisco, Calif.
SECRETARY—J. G. BOLLINGER, Air Reduction Sales, Park & Halleck Sts., Emeryville, Calif.

SAN JOAQUIN VALLEY
CHAIRMAN—G. D. ATMORE, 401 Santa Barbara St., Santa Paula, Calif.
SECRETARY—H. S. NIX, Taft Union H. S. & Jr. College, Box 1364, Taft, Calif.

ST. LOUIS 2nd Fri.
CHAIRMAN—L. H. DODD, American Inst. of Steel Const., 1405 Paul Brown Bldg., St. Louis, Mo.
SECRETARY—M. B. SCIOLETICH, Combustion Engrg. Co., Heine Boiler Div., St. Louis, Mo.

SOUTH TEXAS
CHAIRMAN—G. W. WOODS, Hughes Tool Co., Houston, Texas
SECRETARY—W. H. GREER, Box 175, Houston, Texas

TULSA, OKLAHOMA
CHAIRMAN—F. A. HOFFMAN, Tulsa Boiler & Mach. Co., Tulsa, Okla.
SECRETARY—JAMES B. DAVIS, Tulsa Testing Labs., Tulsa, Okla.

WASHINGTON, D. C. 2nd Tues.
CHAIRMAN—B. B. SWOPE, Southern Oxygen Co., Arlington, Va.
SECRETARY—E. BROOKER, 129 South Buchanan St., Arlington, Va.

WESTERN NEW YORK Last Mon.
CHAIRMAN—G. M. TREFTS, III, Farrar & Trefts, Inc., Buffalo, N. Y.
SECRETARY—D. W. PATTERSON, Federal Mach. & Welder Co., Buffalo, N. Y.

WICHITA, KANSAS
CHAIRMAN—H. CHRISTOPHER, 1220 Blane St., Wichita, Kans.
SECRETARY-TREAS.—K. O. HOUSER, Kansas Gas & Electric Co., Wichita, Kansas

YORK—CENTRAL PENNA.
CHAIRMAN—E. J. BRADY, Alloy Rods Corp., 501 Prospect St., York, Penn.
SECRETARY—C. B. Herrick, 628 S. Pershing Ave., York, Pa.

YOUNGSTOWN (OHIO) 2nd Mon.
CHAIRMAN—ROBERT E. HAAS, P. O. Box 1350, Warren, Ohio
SECRETARY-TREAS.—E. J. DEL VECCHIO, Taylor-Winfield Corp., Warren, Ohio